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ERRATA.

Vol. xxxiv, page 136, line 8 from top, for *silver* read *silica;* page 227, line 12 from top, for MOREHEAD read MORELAND; line 30, for single read *simple;* line 32, for required read *acquired.*

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[THIRD SERIES.]

ART. I.—*The Viscosity of Steel and its Relations to Temperature;* by CARL BARUS.

THIS paper is to be restricted to a discussion of the relation between torsional viscosity and temperature, as observed with steel in different states of hardness. Some mention of the effect of stress on the amount of viscous motion in solids is, however, unavoidable; and the experiments lead naturally to the investigation of a more general method, by which the instantaneous deformation and the gradual deformation produced by stress may be coördinated. The data already show that imperceptible gradations lead from the purely viscous deformation which follows strains within the elastic limits, to the sudden, permanent set which follows strains beyond the elastic limits.

Method of measurement.

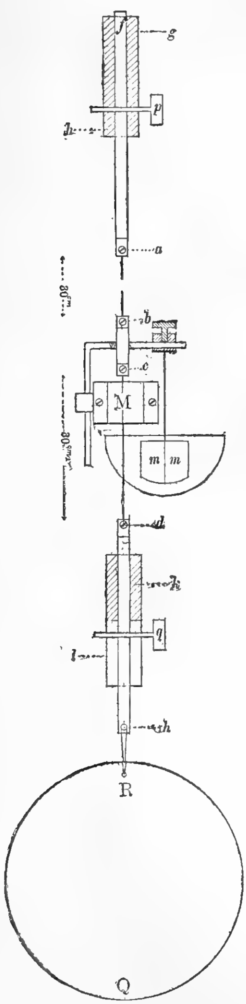
Method.—Given a continuous straight steel wire of length L, to which a convenient rate of twist, τ, has been imparted. Consider two right sections whose distance apart is the unit of length and let φ be the amount of viscous angular motion of the first relative to the second, during the time t. The relation between φ and t is necessarily complex; but if t be taken sufficiently small, the variation of φ within this interval will be uniform. Suppose the wire to be adjusted vertically and provided with an index to register angular motion at a distance b from its lower end. Then will the motion at the index due to the viscous detorsion of two sections whose distance from the lower end is x and whose distance apart is dx $(x>b)$, during the time t be $\psi=\frac{b}{x}\varphi dx$ ....(1)

Hence the total angular motion at the index due to a length of the wire between $x=k$ ($k>b$) and $x=k+a$ will be found by integration to be

$$\psi = b\,\varphi\,l\,\frac{k+a}{k} \quad\text{..........................}\quad (2)$$

Equation (2) implies that viscous detorsion takes place only along the length a of the wire, or that the remainder of the wire is practically rigid with respect to this part. If, as in the present experiments, the temperature of a exceeds that of the rest of the wire by 100° and more, these conditions are nearly enough fulfilled. Equation (2) therefore enables us to calculate φ at once. Knowing φ or the amount of viscous motion uniformly around an axis, it is not difficult to find the corresponding datum for rectilinear viscous motion, where the strain impressed is a simple shear. I omit this reduction here.

1.



Scale one-fourth.

Apparatus.—In the actual work it is expedient to compare two identical wires, one of which is kept hot, the other cold. These wires are shown in the annexed diagram at *ab* and *cd*. The ends, having been bent loop-shaped, are screwed near the middle of the apparatus to a cross-piece of iron carrying the adjustable mirror M. This is the index referred to in the preceding paragraph, and angular deviations are read off by Gauss' method. To deaden lateral vibrations the mirror is also provided with a cross-vane, *mm*, dipping appropriately into a fixed dish of water. The upper end of the system of wires is screwed to a round steel rod, *af*, which fits snugly in the perforation of the massive fixed piece of brass *gh*. A steel pin, *p*, passing through both brass and steel rod, secures the latter to the former. The lower end of the wires is similarly fastened to the steel rod *dh* and the fixed piece of brass *kl*. To keep the wires tense they are stretched by a weight, RQ; and a part of the lower fixed brass *kl* has therefore been cut away in such a manner that the lower pin q may slide along a plane. The system of wires is therefore free to expand.

To heat the upper wire, a given part of it was surrounded by a special form of vapor bath, without being necessarily in contact with it. This will be described elsewhere. Steam (100°), aniline vapor (190°), and mercury vapor (360°) were consecutively introduced. Errors due to radiation are carefully avoided by appropriate screens.

By removing and then re-inserting the pin q, the wires may be twisted in multiples of 90° for each length, or in multiples of rate of twist (τ) of 3° for each wire. For the given dimensions this is the effect of a couple of 250 g. on one centimeter, for each 3° of rate of twist.

A few critical remarks on the efficiency of the apparatus are in place. In most of the experiments made the torsional deformation is so great that special fiducial marks to register the possible motion of the fixed pieces gh and kl are superfluous. Indeed, for angles as large as those observed, Gauss' method of angular measurement is no longer conveniently applicable, because of the number of corrections which become essential. In future measurements it will be expedient to use other methods. The large deflections, however, made it possible to use the Gauss' method even when the apparatus is thrown into unavoidable vibration; for instance, when the upper wire is surrounded by boiling mercury. In the present work it did not seem necessary to take special precautions for jacketing the lower wire. Its temperature is that of the surrounding air, very nearly, and it is not heated by radiation. In the case of steam and of aniline vapor, the length of the hot part of the upper wire is sharply measurable, but in the present work this could not be so satisfactorily done for mercury vapor. Regarding the mode of heating, there are two methods available: the wire may either be heated and the twist then applied, or the wire may be twisted to the desired amount before heating. The former of these methods eliminates the time error, but it is difficult to obtain an accurate reading for the zero-point, i. e., the scale reading for the twisted system before heat is applied. Hence the other method was adopted, in which the invariability of the zero referred to can be satisfactorily tested before each experiment. The error is the time consumed in heating the wire, and in the second part of the observation, the time consumed in cooling the wire after heating. Special means for cooling were not applied. When the motion is great, it is desirable to have the index-mirror adjustment light, though the device used was not perhaps objectionably heavy.

The immediate effect of heating the upper wire is an expansion of the system. Hence if the part of the low fixed brass kl, along which the pin q is free to slide, be not plane and true, there will be a tendency to rotate the system. If, however, the

twist be alternately applied positively and negatively, this expansion error is eliminated by commutation. This safeguard was invariably applied. When the twist stored amounts to 180° for each wire, its sign may often be reversed and readings made without necessarily readjusting the mirror. For smaller twists the mirror must be readjusted. Larger twists were not applied because of liability to permanent set of the wire so twisted.

The wires used are Stubs' best steel, hardened and tempered electrically, as described elsewhere.*

Experimental Results.

Residual twist.—The following experiments have an introductory and suggestive character. Two glass-hard wires with their ends bent loop-shaped are fastened firmly together at one end of each. The other ends are then twisted $\tau°$ against each other and also fastened. This *twisted system* of glass-hard wires, or system in which a rate of twist of 3° or 6° has been stored, are then annealed at divers temperatures during stated times as shown in the tables. The amount of twist lost during annealing is measured by determining the angle between the planes of the upper and lower loops of each wire before and after annealing. A gallows arrangement by which a needle is suspended over a divided circle by the steel wire itself is used for measurement.

The tables contain the number, length (L) and diameter (2ρ) of the glass-hard wires used for each couple; also the temperature and the time (h) in hours, during which the couples are annealed. They contain, furthermore, the amount of viscous detorsion (Δ_1, Δ_2) or twist lost during annealing, for each of the times specified, and each of the wires; finally, the amount of twist stored in each wire of the system. This amount is equal to the twist nominally applied, minus the angle between the plane of the loops. Allowance is made for the amount of permanent set produced by mere manipulatory twisting of the cold wires. When this exceeds 10°, the Δ is discarded. The error of angular measurement is probably not greater than a few degrees.

In the second part of the table the wires S and T are soft.

* U. S. Geol. Survey, Bull. 14, p. 29, 1885. Compare with the above method the one used by Dr. Strouhal and myself in studying the relation of hardness and viscosity (this Journal, xxxii, p. 7, 1886).

TABLE 1.—RESIDUAL TWIST. RODS GLASS-HARD.

No.	Annealed at	h	Δ_1	Δ_2	Twist.
A and B. $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	100°	0·00 1·08 2·08 3·58	0·0 57° 64 70	— — — —	180°—7°
C and D $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	100°	0·00 0·17 0·67 2·00	— — — —	—0·0 —36° —64 —70	180°—10°
E and F $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	190°	0·00 0·10 0·80	— — —	—0·0 —123° —153	180°—25°
G and H $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	190°	0·00 0·10 1·00	— — —	—0·0 —104° —130	180°—2°
I and J $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	190°	0·00 0·08 1·20	0 39° 57	0 52° 69	90°—10°
K and L $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 166°	0 148°	180°—20°
M and N $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 180°	0 166°	180°—10°
O and P $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 77°	0 71°	90°—8°
Q and R $L=31^{cm}$ $2\rho=0{\cdot}043^{cm}$	360°	0·00 0·30	0 156°	0 165°	180°—8°
S and T $L=31^{cm}$ $2\rho=0{\cdot}043^{cm}$	360°	0·00 0·30	0 48°	0 54°	180°—2°

This table contains results which may be expressed as follows: the viscous detorsion produced by the action of any temperature on a twisted system of glass-hard steel wires, increases gradually at a rate diminishing continuously through infinite time, diminishing slowly in case of low temperatures (< 200°), rapidly at first and then again slowly at high temperatures (> 200°); so that the residual twist corresponding to any given temperature is reached asymptotically. Moreover, the strain carried by the glass-hard twisted system is almost completely annulled when the temperature at which annealing takes place exceeds 350°. These results are so strikingly similar to the *thermoelectric effect** produced by annealing glass-hard steel, that the present purely mechanical result may

* U. S. Geol. Surv., Bull. 14, pp. 55, 95, 1885.

safely be used to interpret the electrical result: in both experiments we observe mechanical strains disappearing under like conditions.

The table contains another important result: by comparing the second part of the table with the first, it appears that the effect of temperature in decreasing the viscosity of steel is greater in proportion as steel is harder. For where the twist τ is stored between two glass-hard wires it is found to have almost completely vanished after annealing; but where the same twist is stored between two soft wires less than one-third of it has vanished after annealing. The curious inference that in so far as its viscous properties are concerned, steel is much more susceptible to temperature when it is hard than when it is soft, will be carefully discussed in the following pages by aid of the apparatus already described.

Torsional viscosity and temperature.—The data of the following thirteen tables give a clear description of the viscosity of steel for temperatures between 0° and 400°, and for all degrees of hardness. These data are readily intelligible. T denotes the temperature of the hot part, T' the temperature of the cold part of the wires in the apparatus, p. 2. The distance between mirror and scale was 360^{cm} throughout. L, b, k, a, have the signification already given, being the total length of wires, the distance of mirror above their lower end, the length of their cold and of their hot parts, respectively, in centimeters. The tempers of the rods (diameter 2ρ) are expressed by the temperature at which the originally glass-hard rod was annealed. Soft rods are annealed at red heat. The tabular arrangement contains the date and the time (h_0) in hours and fractions of an hour, of each of the angular detorsions φ, in radians. φ has been defined, p. 1. It denotes the angular viscous motion between two right sections whose distance apart is the unit of length, when the temperature of the included wire is $T°$ and the original rate of twist τ for the given diameter 2ρ. Identical signs of τ and φ refer to angular motions in the same sense, and since τ and φ agree for the cold rod this is invariably of greater viscosity.

TABLE 1.

$T=100°$; $T'=20°$. $L=60^{cm}$. $b=30^{cm}$. $A=26^{cm}$. $k=34^{cm}$. Rods: No. 1, soft; No. 2, soft } $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
18/2, 0h 53m	0·00	0·00	*	19/2, 2h 44m	1·45	−1·97	Steam off.
				3 00	1·72	−1·76	
0 56	0·05	−1·57	Steam on.	25	2·13	−1·04	
1 00	C·12	−1·66		4 55	3·63	−0·96	
15	0·37	−1·85		24/2, 10h 42m	0·00	0·00	‡
45	0·87	−2·17					
2 45	1·87	−2·45		10 45	0·05	1·13	Steam on.
3 50	2·95	−2·74		59	0·29	1·59	
4 30	3·63	−2·99		11 12	0·50	1·74	
				27	0·75	1·80	
4 33	3·67	−2·80	Steam off.	59	1·30	1·89	
44	3·85	−2·36		12 23	1·66	1·92	
54	4·02	−2·21		1 15	2·50	1·95	
19/2, 9 30	20·67	−1·88					
19/2, 1h 17m	0·00	−0·00	†	1 22	2·65	1·62	Steam off.
				30	2·80	1·33	
1 25	0·13	−1·73	Steam on.	50	3·13	1·14	
56	0·65	−1·95		2 12	3·50	1·01	
2 14	0·95	−2·04		3 30	4·80	0·94	
40	1·38	−2·12					

* τ (cold rod)—6°, imparted after heating.
† τ (cold rod)—6°, imparted before heating.
‡ τ (cold rod) + 6°, imparted before heating.

TABLE 2.

$T=100°$; $T'=20°$. $A=26^{cm}$. $b=30^{cm}$. $L=60^{cm}$. $k=34^{cm}$. Rods: No. 3, ann'ld, 100° 9h; No. 4, ann'ld, 100° 9h } $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
24/2, 4h 36m	0·00	−0·00	*	26/2, 10h 02m	0·00	0·00	‡
4 43	0·12	−4·57	Steam on.	10 10	0·13	−11·95	Steam on.
45	0·15	−5·62		15	0·21	−13·26	
55	0·32	−13·21		20	0·30	−14·70	
5 10	0·57	−15·91		25	0·39	−15·62	
				30	0·46	−16·42	
5 15	0·65	−12·31	St'm off.	44	0·70	−18·22	
25/2, 9 40	17·07	−10·43		55	0·89	−18·29	
25/2, 10h 00m	0·00	0·00	†	11 04	1·03	−19·97	
				16	1·22	−20·83	
10 06	0·10	8·87	Steam on.	43	1·70	−22·34	
10	0·18	14·10		57	1·92	−23·07	
20	0·32	18·13		12 55	2·87	−25·20	
25	0·42	19·60					
30	0·50	20·12		1 09	3·10	−24·14	Steam off.
34	0·56	20·70		30	3·41	−23·46	
				55	3·88	−23·34	
45	0·75	19·81	Steam off.	3 12	5·16	−22·66	
11 00	1·00	19·06					
28	1·47	18·70					
1 40	3·67	18·40					
26/2, 9 37	23·62	18·05					

* τ (cold rod)—6° imparted before heating.
† τ (cold rod) + 6° imparted before heating, immediately after *.
‡ τ (cold rod)—6° imparted before heating, immediately after †.

TABLE 3.

$T=100°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 5, annealed, 190°, 2^h; No. 6, annealed, 190°, 2^h; $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times 10^3$	
26/2, $3^h\ 57^m$	----	0·00	*
4 15	0·00	0·00	
4 20	0·09	−4·83	Steam on.
25	0·17	−5·79	
34	0·32	−6·75	
40	0·42	−7·18	
51	0·60	−7·64	
5 10	0·92	−8·24	
5 17	1·03	−7·53	St'm off.
28/2, 9 52	41·62	−5·76	
28/2, $9^h\ 58^m$	----	0·00	†
10 20	0·00	0·00	
10 27	0·12	3·62	Steam on.
34	0·23	8·01	
41	0·35	9·03	
51	0·52	9·82	
11 02	0·70	10·44	
33	1·22	11·38	
54	1·57	11·80	
12 17	1·95	12·20	
50	2·50	12·63	
1 04	2·73	11·27	Steam off.
15	2·92	10·82	
26	3·10	10·60	
42	3·37	10·45	
28/2, $1^h\ 49^m$	----	0·00	‡
2 05	0·00	0·00	
2 15	0·17	−6·06	Steam on.
20	0·25	−7·29	
30	0·42	−8·60	
35	0·50	−9·05	
51	0·77	−9·85	
3 13	1·12	−10·44	
20	1·25	−10·80	
45	1·67	−11·30	

Date.	h_0	$\phi\times 10^3$	
28/2, $3^h\ 55^m$	1·83	−10·28	Steam off.
4 05	2·00	−9·72	
54	2·82	−9·18	
5/3, $10^h\ 20^m$	0·00	−0·00	*
10 26	0·10	−2·38	Steam on.
30	0·16	−2·93	
35	0·25	−3·07	
44	0·40	−3·23	
56	0·60	−3·45	
11 01	0·68	−2·90	Steam off.
06	0·76	−2·38	
13	0·88	−1·90	
23	1·05	−1·55	
31	1·18	−1·39	
5/3, $11^h\ 33^m$	0·00	0·00	†
11 35	0·06	3·06	Steam on.
54	0·36	7·67	
12 03	0·50	8·29	
11	0·63	8·60	
12 15	0·70	8·28	Steam off.
24	0·85	7·51	
35	1·03	7·10	
45	1·20	6·87	
5/3, $1^h\ 46^m$	0·00	−0·00	‡
1 52	0·10	−4·26	Steam on.
2 03	0·28	−7·46	
08	0·37	−7·90	
15	0·48	−8·26	
24	0·63	−8·62	
2 31	0·75	−7·98	Steam off.
41	0·92	−7·12	
51	1·08	−6·76	
3 11	1·41	−6·49	

* τ (cold rod)—6°, imparted before heating.
† τ (cold rod)+6°, imparted before heating, immediately after *.
‡ τ (cold rod)—6°, imparted before heating, immediately after †.

TABLE 4.

$T=100°$; $T'=20°$; $a=26^{\mathrm{cm}}$; $b=30^{\mathrm{cm}}$; $L=60^{\mathrm{cm}}$; $k=34^{\mathrm{cm}}$. Rods: No. 7, annealed, 360°; No. 8, annealed, 360°; $2\rho=0·083^{\mathrm{cm}}$.

Date.	h_0	$\phi\times10^3$	
1/3, $10^{\mathrm{h}}\ 30^{\mathrm{m}}$	0·00	0·00	*
10 35	0·08	2·16	Steam on.
47	0·28	2·68	
59	0·48	2·86	
11 12	0·70	2·98	
22	0·87	3·05	
45	1·25	3·17	
12 00	1·50	3·22	
12 15	1·75	2·27	Steam off.
57	2·45	1·79	
1 17	2·78	1.76	
37	3·12	1·74	
1/3, $1^{\mathrm{h}}\ 40^{\mathrm{m}}$	0·00	0·00	†
47	0·12	−2·63	St'm on.
51	0·18	−3·40	
58	0·30	−4·04	

Date.	h_0	$\phi\times10^3$	
1/3, $2^{\mathrm{h}}\ 09^{\mathrm{m}}$	0·48	−4·43	Steam on.
35	0·92	−4·82	
3 04	1·33	−5·04	
24	1·73	−5·15	
43	2·05	−5·23	
4 55	2·25	−4·45	Steam off.
5 03	2 40	−4·15	
25	2·75	−3·86	
1/3, $4^{\mathrm{h}}\ 40^{\mathrm{m}}$	0·00	0·00	‡
4 47	0·10	2·32	Steam on.
55	0·25	3·47	
5 05	0·42	3·95	
15	0·58	4·12	
5 22	·70	3·67	St'm off.
2/3, $9^{\mathrm{h}}\ 42^{\mathrm{m}}$	17·03	2·47	

* τ (cold rod) + 6°, imparted before heating.
† τ (cold rod) − 6°, imparted before heating, immediately after *.
‡ τ (cold rod) + 6°, imparted before heating, immediately after ‡.

TABLE 5.

$T=100°$; $T'=20°$; $L=60^{\mathrm{cm}}$; $b=30^{\mathrm{cm}}$; $a=26^{\mathrm{cm}}$; $k=34^{\mathrm{cm}}$. Rods: No. 9, annealed, 480°; No. 10, annealed, 480°; $2\rho=0·083^{\mathrm{cm}}$.

Date.	h_0	$\phi\times10^3$	
2/3, $10^{\mathrm{h}}\ 53^{\mathrm{m}}$	0·00	0·00	*
11 00	0·07	1·35	Steam on.
10	0·17	2·13	
21	0·28	2·29	
31	0·38	2·39	
40	0·47	2·46	
58	1·05	2·51	
12 15	1·22	2·56	
55	2·02	2·65	
1 00	2·07	2·33	Steam off.
07	2·14	1·88	
1 24	2·31	1·44	
34	2·41	1·34	
43	2·50	1·28	
2 00	3·07	1·21	
2/3, $2^{\mathrm{h}}\ 05^{\mathrm{m}}$	0·00	0·00	†
2 14	0·15	−1·88	Steam on.
19	0·23	−2·49	
24	0·31	−2·78	
32	0·45	−2·98	
45	0·66	−3·12	
3 00	0·92	−3·22	
08	1·05	−3·27	
15	1·16	−3·31	
3 23	1·30	−2·77	Staem on.
32	1·45	−2·31	
38	1·55	−2·12	
47	1·70	−1·97	
58	1·88	−1·88	
4 11	2·10	−1·81	
3/3, $10^{\mathrm{h}}\ 02^{\mathrm{m}}$	0·00	0·00	‡

Date.	h_0	$\phi\times10^3$	
3/3, $10^{\mathrm{h}}\ 05^{\mathrm{m}}$	0·05	1·41	Steam on.
10	0·13	2·44	
15	0·21	2·78	
25	0·38	2·91	
31	0·48	2·95	
43	0·68	2·99	
11 02	1·00	3·11	
11 07	1·08	2·76	Steam off.
15	1·21	2·25	
25	1·38	1·88	
37	1·55	1·70	
55	1·88	1·57	
12 02	2·00	1·54	
3/3, $12^{\mathrm{h}}\ 12^{\mathrm{m}}$	0·00	0·00	§
12 17	0·08	−1·85	Steam on.
22	0·16	−2·42	
28	0·26	−2·67	
33	0·35	−2·75	
44	0·53	−2·87	
55	0·72	−2·95	
1 08	0·90	−3·02	
19	1·10	−3·07	
30	1·30	−3·11	
56	1·74	−3·15	
2 00	1·80	−2·87	Steam off.
06	1·90	−2·48	
12	2·00	−2·19	
22	2·16	−1·94	
33	2·35	−1·79	
49	2·61	−1·72	

* τ (cold rod) + 6°, imparted before heating.
† τ (cold rod) − 6°, imparted before heating, immediately after *.
‡ τ (cold rod) + 6°, imparted before heating.
§ τ (cold rod) − 6°, imparted before heating, immediately after ‡.

TABLE 6.

$T=100°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$\phi\times10^3$	
4/3, $10^h\ 08^m$	0·00	0·00	*
10 13	0·08	1·57	Steam on.
18	0·16	2·17	
24	0·28	2·33	
33	0·41	2·41	
47	0·65	2·52	
57	0·83	2·60	
11 12	1·06	2·69	
20	1·20	2·74	
40	1·53	2·86	
11 45	1·62	2 64	Steam off.
11 55	1·78	2·01	
12 05	1·95	1·89	
15	2·11	1·78	
29	2·35	1·69	

Date.	h_0	$\phi\times10^3$	
4/3, $12^h\ 59^m$	2·85	1·62	St'm off.
1 40	3·53	1·58	
4/3, $1^h\ 57^m$	0·00	0·00	†
2 04	0·11	−2·53	Steam on.
09	0·20	−2·89	
19	0·36	−3·16	
28	0·51	−3·19	
40	0·71	−3·26	
3 06	1·15	−3·36	
3 10	1·21	−3·20	Steam off.
16	1·31	−2·78	
24	1·45	−2·52	
33	1·60	−2·37	
44	1·78	−2·27	

* τ (cold rod)$+6°$, imparted before heating.
† τ (cold rod)$-6°$, imparted before heating, immediately after *.

TABLE 7.

$T=190°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 5, annealed, 190°; No. 6, annealed, 190°; $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$\phi\times10^3$	
7/3, $9^h\ 55^m$	0·00	0·00	*
10 00	0·08	−7·45	Vapor on.
04	0·15	−22·20	
10	0·25	−23·58	
19	0·40	−23·72	
7/3, $12^h\ 27^m$	0·00	0·00	†
12 33	0·10	21·91	Vapor on.
36	0·15	34·46	
40	0·22	40·25	
42	0·25	42·54	
12 55	0·47	40·52	Vap. off.
1 40	1·22	39·34	
7/3, $2^h\ 35^m$	0·00	0·00	‡
2 45	0·17	−17·13	Vapor on.
47	0·20	−18·38	
53	0·30	−20·22	
3 10	0·58	−23·10	
19	0·73	−23·56	
43	1·13	−26·41	
3 53	1·30	−25·49	Vapor off.
4 07	1·53	−25·02	
45	2·17	−24·86	
8/3, 9 00	18·42	−24 86	
8/3, $9^h\ 35^m$	0·00	0·00	§
9 43	0·13	6·20	Vapor on.
45	0·17	9·81	
48	0·22	13·27	

Date.	h_0	$\phi_0\times10^3$	
9 50.	0·25	14·70	Vapor on.
53	0·30	16·04	
56	0·35	17·13	
10 00	0·42	18·39	
08	0·55	20·28	
15	0·67	21·71	
27	0·87	23·76	
40	1·08	25·66	
47	1·20	26·83	
11 00	1·42	25·66	Vapor off.
20	1·75	25·09	
55	2·33	24·94	
8/3, $12^h\ 00^m$	0·00	0·00	‖
08	0·13	−10·84	Vapor on.
10	0·17	−12·51	
12	0·20	−13·68	
15	0·25	−14·98	
18	0·30	−16·06	
21	0·35	−16·92	
25	0·42	−17·92	
30	0·50	−19·02	
35	0·58	−20·01	
40	0·67	−20·77	
45	0·75	−21·44	
50	0·83	−22·03	
1 00	1·00	−23·04	
1 12	1·20	−22 20	Vapor off.
30	1·50	−21·73	
45	1·75	−21·67	

* τ (cold rod)$-6°$, imparted before heating.
† τ (cold rod)$+6°$, imparted before heating, immediately after *.
‡ τ (cold rod)$-3°$, imparted before heating, immediately after †.
§ τ (cold rod)$+3°$, imparted before heating, immediately after ‡.
‖ τ (cold rod)$-3°$, imparted before heating, after §.

TABLE 8.

$T=190°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 7, annealed, 360°; No. 8, annealed, 360°; $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
8/3, $2^h\ 11^m$	0·00	0·00	*	8/3, $5^h\ 01^m$	1·33	−3·86	Vap. off.
2 20	0·15	3·14	Vapor on.	10	1·48	−3·51	
25	0·23	3·71		9/3, $9^h\ 27^m$	0·00	0·00	‡
36	0·42	3·95		9 32	0·08	1·26	Vapor on.
3 05	0·90	4·15		40	0·21	3·01	
3 12	1·02	3·38	Vap. off.	10 35	1·13	4·51	
35	1·40	2·79		48	1·35	4·56	
8/3, $3^h\ 41^m$	0·00	0·00	†	11 02	1·58	3·44	Vapor off.
3 50	0·15	−3·37	Vapor on.	07	1·66	3·28	
57	0·27	−4·48		17	1·83	3·13	
4 08	0·45	−4·81		26	1·98	3·07	
26	0·75	−4·88					
52	1·18	−4·98					

* τ (cold rod) + 3°. imparted before heating.
† τ (cold rod) − 3°, imparted before heating, immediately after *.
‡ τ (cold rod) + 3°, imparted before heating, immediately after †.

TABLE 9.

$T=190°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 9, annealed, 450°; No. 10, annealed, 450°; $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
9/3, $11^h\ 50^m$	0·00	0·00	*	9/3, $2^h\ 07^m$	0·86	2·74	Vapor off.
11 55	0·08	−1·63	Vapor on.	14	0·98	2·33	
12 00	0·16	−1·94		27	1·03	2·06	
06	0·26	−1·97		35	1·33	2·02	
15	0·41	−2·00		9/3, $3^h\ 30^m$	0·00	0·00	‡
35	0·75	−2·01		3 36	0·10	−2·74	Vapor on.
12 44	0·90	−1·03	Vap. off.	40	0·17	−3·00	
51	1·01	−0·73		47	0·28	−3·08	
9/3, $1^h\ 15^m$	0·00	0·00	†	55	0·42	−3·10	
1 21	0·10	2·67	Vapor on.	4 16	0·77	−3·29	
35	0·33	3·43		4 30	1·00	−1·99	Vapor off.
43	0·46	3·44		41	1·18	−1·71	
2 00	0·75	3·52		10/3, $9^h\ 30^m$	18·00	−1·55	

* τ (cold rod) − 3°, imparted before heating.
† τ (cold rod) + 3°, imparted before heating, immediately after *.
‡ τ (cold rod) − 3°, imparted before heating, immediately after †.

TABLE 10.

$T=190°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times10^3$	
10/3, $10^h\ 05^m$	0·00	0·00	*
10 11	0·10	−1·73	Vapor on.
16	0·18	−2·36	
23	0·30	−2·52	
31	0·43	−2·56	
40	0·58	−2·61	
51	0·76	−2·66	
11 11	1·10	−1·51	Vapor off.
25	1·33	−1·47	
42	1·63	−1·34	
10/3, $11^h\ 49^m$	0·00	0·00	†
12 04	0·25	2·63	Vapor on.
15	0·43	2·86	
24	0·58	2·97	
40	0·85	3·06	
12 45	0·93	2·59	Vapor off.
53	1·06	2·16	
1 30	1·68	1·87	

Date.	h_0	$\phi\times10^3$	
10/1, $1^h\ 43^m$	0·00	0·00	‡
1 52	0·15	−2·63	Vapor on.
57	0·23	−2·89	
2 06	0·38	−3·00	
15	0·53	−3·08	
23	0·66	−3·12	
2 29	0·76	−2·59	Vapor off.
37	0·90	−2·17	
51	1·13	−1·90	
10/3, $3^h\ 08^m$	0·00	0·0	§
3 20	0·20	24·3	Vap. on.
10/3, $4^h\ 15^m$	0·00	0·0	‖
30	0·25	− 0·9	
4 45	0·50	−46·0	Vap. on.

* τ (cold rod)—3°, imparted before heating.
† τ (cold rod)+3°, imparted before heating, immediately after *.
‡ τ (cold rod)—3°, imparted before heating, immediately after †.
§ τ (cold rod)+6°, imparted before heating, immediately after ‡.
‖ τ (cold rod)—6°, imparted before heating, immediately after §.

TABLE 11.

$T=360°$; $T'=20°$; $a=9^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times10^3$	
11/3, $11^h\ 25^m$	0·00	0·00	*
11 34	0·15	− 9·9	Vapor on.
36	0·18	−13·0	
39	0·23	−14·8	
44	0·32	−16·6	
47	0·37	−17·9	
53	0·47	−19·0	
11 59	0·57	−16·8	Vapor off.
12 05	0·67	−15·9	
10	0·75	−15·4	
18	0·88	−15·1	
27	1·03	−14·8	
1 13	1·80	−14·3	
11/3, $2^h\ 03^m$	0·00	0·00	†
2 06	0·05	9·8	Vapor on.
09	0·10	25·6	
11	0·13	35·4	
12	0·15	44·9	
15	0·20	53·4	
18	0·25	57·1	

Date.	h_0	$\phi\times10^3$	
11/3, $2^h\ 21^m$	0·30	60·1	Vapor on.
25	0·37	61·4	
35	0·53	63·2	
2 54	0·85	59·7	Vapor off.
3 01	0·97	59·5	
28	1·42	59·3	
11/3, $4^h\ 25^m$	0·00	0·00	‡
4 32	0·10	−22·2	Vapor on.
34	0·15	−31·9	
36	0·18	−36·0	
39	0·23	−40·4	
41	0·27	−41·9	
45	0·33	−44·1	
51	0·43	−45·7	
57	0·53	−47·2	
5 10	0·75	−49·6	
5 17	0·87	−46·3	Vapor off.
26	1·02	−44·9	
12/3, $9^h\ 25^m$	17·00	−43·3	

* τ (cold rod)—3°, imparted before heating.
† τ (cold rod)+3°, imparted before heating, immediately after *.
‡ τ (cold rod)—3°, imparted before heating, immediately after †.

TABLE 12.

$T=360°$; $T'=20°$; $a=9^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 9, annealed, 450°; No. 10, annealed, 450°. $2\rho=0·082^{cm}$.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
12/3, 10^h 04^m	0·00	−0·0	*	12/3, 1^h 10^m	0·92	50·5	Vap. off.
				2 00	1·75	49·0	
10 10	0·10	− 6·0	Vapor on.	12/3, 2^h 15^m	0·00	0·0	‡
31	0·45	−24·6					
49	0·75	−29·6		2 19	0·06	−12·6	Vapor on.
57	0·88	−31·8		20	0·08	−19·0	
				25	0·16	−33·7	
11 15	1·18	−25·8	Vapor off.	27	0·20	−38·8	
27	1·38	−25·2		28	0·22	−42·3	
59	1·92	−24·8		36	0·35	−50·0	
12/3, 12^h 15^m	0·00	0·0	†	47	0·63	−55·5	
				3 13	0·96	−61·0	
12 25	0·17	36·6	Vapor on.				
27	0·20	41·3		3 20	1·08	−57·3	Vapor off.
30	0·25	45·3		32	1·28	−54·9	
36	0·35	50·0		48	1·55	−54·4	
45	0·50	54·0					
55	0·67	55·5					

* τ (cold rod)−3°, imparted before heating.
† τ (cold rod)+3°, imparted before heating, immediately after *.
‡ τ (cold rod)−3°, imparted before heating, immediately after †.

TABLE 13.

$T=360°$; $T'=20°$; $a=9^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods: No. 7, annealed, 360°; No. 8, annealed, 360°.

Date.	h_0	$\phi\times10^3$		Date.	h_0	$\phi\times10^3$	
14/3, 10^h 00^m	0·00	0·0	*	14/3, 3^h 19^m	0·00	0·0	‡
10 03	0·07	−25·2	Vapor on.	3 22	0·05	5·9	Vapor on.
05	0·10	−34·2		23	0·07	11·4	
06	0·12	−41·0		24	0·08	17·9	
07	0·13	−47·2		25	0·10	24·8	
09	0·17	−53·0		27	0·12	33·8	
10	0·18	−57·3		28	0·15	38·6	
13	0·23	−63·6		29	0·17	44·5	
15	0·27	−66·4		32	0·22	52·8	
				33	0·23	56·3	
10 19	0·33	−65·6	Vapor off.	35	0·27	58·9	
31	0·53	−63·6		37	0·30	63·0	
40	0·68	−63·2		40	0·35	66·0	
11 04	1·08	63·0					
14/3, 1^h 32^m	0·00	0·00	†	3 55	0·60	60·0	Vapor off.
				4 12	0·88	59·0	
1 38	0·10	−21·6	Vapor on.	26	1·12	59·0	
40	0·13	−32·3		14/3, 4^h 45^m	0·00	0·0	§
43	0·18	−41·3					
46	0·23	−48·2		4 49	0·07	− 8·2	Vapor on.
51	0·32	−54·7		50	0·08	−12·6	
59	0·45	−60·3		52	0·12	−31·3	
2 02	0·50	−62·6		54	0·15	−40·4	
11	0·65	−66·5		56	0·18	−47·2	
				57	0·20	−51·6	
2 26	0·90	−60·8	Vap. off.	5 05	0·33	−57·7	
50	1·27	−60·1					
				5 24	0·65	−53·4	Vap. off.

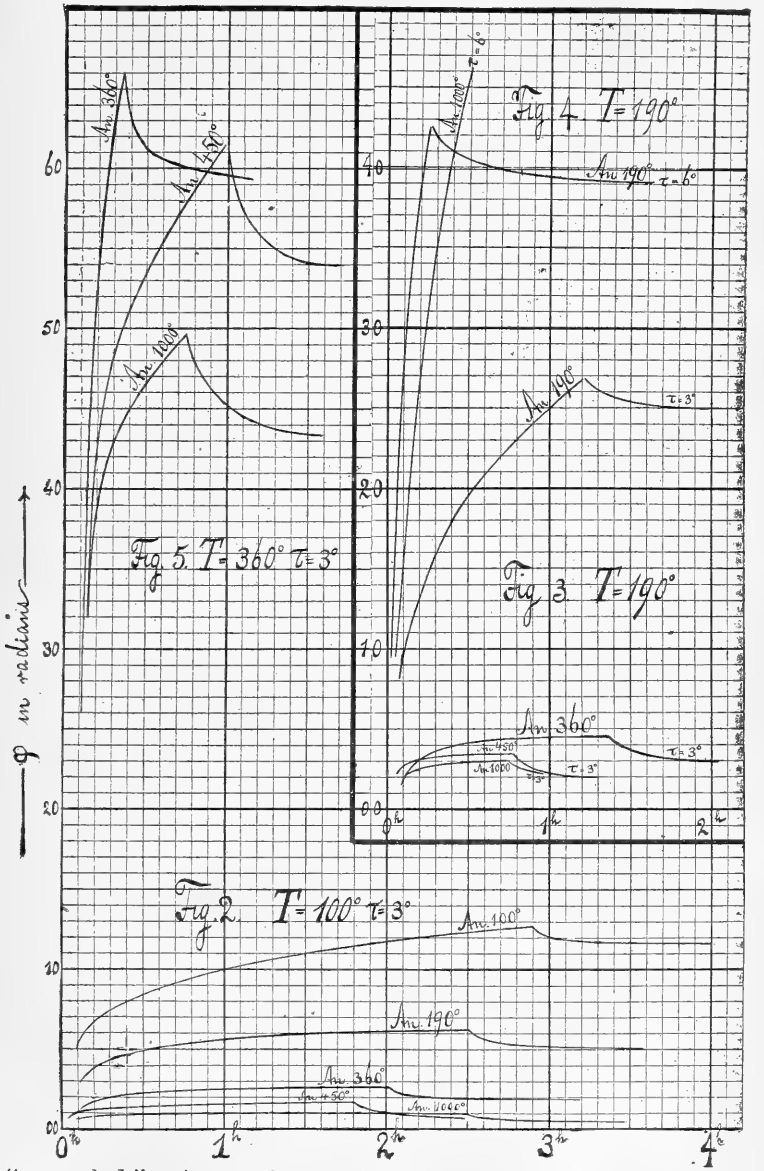
* τ (cold rod)−3°, imparted before heating.
† τ (cold rod)−3°, imparted before heating, after *.
‡ τ (cold rod)+3°, imparted before heating, immediately after †.
§ τ (cold rod)−3°, imparted before heating, immediately after ‡.

A few remarks on the tables are here in place. Large angles φ, for the measurement of which Gauss' method is inconvenient, were calculated directly from the tangents. The error is everywhere within 1 per cent. In table 3 and more particularly in special experiments the observations on the constancy of the scale-reading when the temperatures of both upper and lower wires are identical, prove that errors due to differences of viscosity in the cold wires are negligible. No motion is perceptible until heat has been applied. The difficulty encountered in fixing the zero of time has already been mentioned. The curves are therefore correct in their vertical dimensions, but may have been shifted laterally as much as is indicated in each table by the interval between the parts marked "vapor on" and "vapor off." It has also been stated that the results for mercury are too large because of the difficulty in accurately defining the length of the hot part a. Finally two sets of experiments were made with soft wire (Rods, Nos. 1, 2, 11, 12) because the viscous properties of soft wire are not sharply definable. The curves lie sometimes above, sometimes below the mean zone for annealed 450°. This vagueness of the soft state is largely due to strains incidentally impressed. When a positive twist immediately follows a negative twist, or vice versa, the values of φ (cæt. par.) are larger than for the case of an untwisted wire. It is therefore to be noted that in the arrangement of apparatus employed the permanent set of any prolonged torsion is added to the following torsion, particularly in the case of high T. But this discrepancy is probably negligible.

Deductions.

Viscosity and Temperature.—The behavior of a given steel wire varies with the character and with the amount of twist it has received. These variations are not insignificant. Hence it is expedient to construct a diagram of the mean viscous motion for each degree of hardness, and then to discuss the secondary variations with reference to this diagram. In figures 2, 3, 4 and 5, φ, the angular torsion in radians (p. 1) is exhibited as a function of time in hours, when wires in all degrees of hardness are exposed to degrees of temperature (T) of 100°, 190° and 360° respectively. The series is made complete when the rate of twist (τ) is 3°, the values of φ corresponding to T=100° (tables 1 to 6) where τ=6° having been divided by 2 to effect this reduction. This operation is probably not rigorous; but it is sufficiently correct for the present purposes. In the case of T=190° experiments were made both for τ=3° (fig. 3), and for τ=6° (fig. 4). All the curves consist of two distinct parts, an anterior ascending branch showing the motion at the high temperature T, and a descending branch showing

the (elastic) effect of cooling from T to room temperature (T'). In both figures and text the abbreviation "An." is used for



"annealed." An. 190° denotes, for instance, that the glasshard steel rod is annealed at 190° until further change of temper is practically imperceptible. Figures 2 to 5 and tables A and 1

to 13 clearly show that the viscous detorsion φ exhibited by steel is very much more influenced by temperature when the steel is hard than when it is soft. In other words, viscosity decreases with temperature (cæt. par.) at much greater rates in hard steel than in soft steel. Again, at the same temperature T, the differences of viscosity are very large when the temper of steel lies between glasshard and annealed 350°. Intermediate differences within this interval are larger in proportion as mean hardness is greater. When temper lies between annealed at 350° and soft, differences of viscosity at the same T are relatively small. In general therefore the variations of viscosity due to temper are marked occurrences during the first phase* of annealing, and nearly vanish during the second phase, a result which corroborates the close analogy between the viscous effects of temper and the thermoelectric effect of temper already pointed out (cf. p. 5).

For the same degree of hardness viscosity increases at an accelerated rate with temperature T. In figure 2, where $T=100°$, the large viscous interval between An. 100° and An. 360° is in striking contrast with the smaller viscous interval An. 360° to An. 1000°, notwithstanding the fact that to avoid erroneous comparisons the latter interval has rather been chosen too large than too small. Indeed, the values for An. 1000° in table 6 would place the locus for soft wire even above the curve An. 450° in figure 2, suggesting the occurrence of a maximum viscosity for $T=100°$. Passing from figure 2 to figure 3 ($T=190°$), the interval between An. 190° and An. 360° is phenomenally increased. The interval An. 360° to An. 1000° is also increased, but only slightly. Again, passing from figure 3 to figure 5 ($T=360°$), the interval of the second phase of annealing (An. 360° to An. 1000°) is largely increased.† The marked tendency of a steel wire annealed from hardness at $t°$ to suffer viscous deformation when exposed to $t°$, is the chief result of the present paper. This tendency decreases with great rapidity in proportion as the temperature of exposure falls below $t°$.

As temperature increases, glass seems to lose viscosity much less rapidly than hard steel, but probably not less rapidly than soft steel. The magnetic instability of glass-hard steel is probably due to its extreme susceptibility to temperature, since every change of temper is the cause of loss of magnetic moment. This close relation between hardness and magnetism is good evidence in favor of the essentially strained character of hard steel.

* This Journal, vol. xxxi, p. 443, 1886.

† Of course the degree of hardest temper to be exposed to T for viscous comparisons is An. T. Harder wires would be annealed at this temperature and the concomitant effects due to changes of temper erroneously confounded with simple viscous motion.

Behavior of other metals.—Kohlrausch,* Streintz,† Schmidt,‡ and Pisati § have discussed the effect of temperature on viscosity. More minute investigations on the relation between viscosity and temperature have recently been made with silver, platinum, iron and german silver, and for temperatures within 100°, by Schroeder.‖ It is in place to advert in passing to certain important accordances between Schroeder's results and the present results. In the data above, one or more alternations of the sign of twist are applied to the steel wires (Tables 1 to 13, particularly Table 3), and the amount of deformation decreases (cæt. par.) with the number of torsions applied gradually toward a limit. This fact has been studied by Wiedemann¶ and by Streintz under the term "accommodation." Schroeder has apparently enlarged the importance of these observations by showing that repeated alternations of temperature from low to high values have the same effect.** It remains to be seen, however, whether this is not an immediate result of the fact that Schroeder's hard-drawn wires are annealed by exposure to 100°. A second result of Schroeder's,†† viz: that the amount of "after-action," as well as the amount of change of after-action due to stated increments of temperature is greatest in silver, of intermediate value in iron, and smallest in german silver, has an important bearing on the present experiments. The present results taken together with the earlier paper of Barus and Strouhal ‡‡ show conclusively that the viscosity of steel and the variation of viscosity due to temperature increase in like order, and in ways which throughout the course of the phenomena are thoroughly analogous. A final result of Schroeder's bearing on the present paper, viz: that the viscous detorsion occurring at 100° is arrested by suddenly lowering the temperature as far as 20° is again fully corroborated by the behavior of steel; but the character of the viscous motion while the temperature either rises or falls does not so fully appear, because a large part of the retrograde movement observed during cooling is here to be ascribed to concomitant changes of the modulus of elasticity produced by temperature. In other

* Kohlrausch: Pogg. Ann., cxxviii, p. 216, 1866; clviii, p. 371, 1876.

† Streintz: Wien. Berichte, lxix, p. 337, 1874.

‡ Schmidt: Wien. Ann., ii, p. 264, 1877.

§ Pisati: Wien, Berichte, lxxx, p. 427, 1879.

‖ Schroeder: Wied. Ann., xxviii, p. 369, 1886.

¶ Wiedemann: Wied. Ann., vi, p. 512, 1879.

** "Ebenso wie das log. Decrement bei Torsionschwingungen zeigt auch die Nachwirkung unter dem Einflusse wiederholter Temperaturänderungen eine Accommodation."

†† "Sowohl die Nachwirkung wie die Änderung derselben mit der Temperatur ist am grössten beim Silberdraht, geringer beim Eisen, am kleinsten beim Neusilberdraht."

‡‡ This Journal, xxxiii, p. 25, 26, 1887.

words relatively large variations of elasticity are superimposed upon and obscure the nature of the viscous detorsion during the interval of transition from high to low temperature, or from low to high temperature. It is because of the mixed character of the retrograde movement that I refrain from using the data for the construction of the temperature relations of the rigidity of steel. If a device for cooling with sufficient rapidity to annul the viscous movement, be applied, then the present method may be used at once for investigating the effect of temperature on rigidity. This I have occasion to show in my next paper.

Sudden and gradual deformation.—In the experiments for $T=100°$ the rate of twist $\tau=6°$ was uniformly applied. The results were then approximately reduced to $\tau=3°$ by merely halving the values of φ. Figure 4 shows that the same strain, $\tau=6°$, applied for $T=190°$, is too large for convenient measurement by Gauss' method. On applying $\tau=3°$ directly, the complete series of results of figure 3 is obtained. Comparing the loci of figure 3 and figure 4, it appears clearly that φ increases very much more rapidly than τ. Moreover, if the rate of increase of τ be 2, the rate of increase of φ is certainly as much as 3 in case of An. 190°, and even more than 10 in case of soft (An. 1000°). It follows therefore very probably that the viscous relations of soft steel to hard steel vary enormously and may even change sign as the stress producing viscous motion passes from low to high values (cf. p. 3). This is an important deduction. For rates of twist less than $\tau=3°$ for the diameter $2\rho=0{\cdot}082^{cm}$, steel is less viscous, and as regards viscosity much more susceptible to the influence of temperature, in proportion as it is harder. For rates of twist greater than $\tau=6°$ steel is less viscous and more susceptible to the influence of temperature in proportion as it is softer. The complete coördination of these facts, in other words the full expression of the viscosity of steel as a function of hardness for all degrees of temperature T and all values of stress τ, will be the key for the explanation of the mechanical behavior of steel and its important bearing on magnetic, electrical and other properties of the metal. To elucidate these remarks I will complete the description of the apparatus with which the present results were obtained.

In the apparatus, figure 1, page 2, suppose the lower (cold) wire to be in connection with clock-work, in such a way that it may be twisted uniformly, at any given velocity, variable at pleasure. Suppose the method of adjusting the index to be such as is suitable for the measurement of angles of any magnitude. If the clock be set in motion from $\tau=0$, the strain will increase at some determinate arbitrary rate. For a given value of T, therefore, a family of curves may be obtained in which

the angular motion of the index ψ_1 for a given wire must be expressible as a function of the time during which twisting has taken place and the rate at which the strain is increased. In other words, if c be the rate of rotation of the lower end of the lower wire, the experimental results may be symbolized by

$$\psi_1 = f_1(t, c_1)$$
$$\psi_2 = f_2(t, c_2)$$
$$\psi_n = f_n(t, c_n),$$

where t is the symbol of time. It follows that the strain per centimeter of the total length L, at any time t, will be ct/L diminished by the amount of viscous motion.* Hence it is experimentally possible and fully feasible to pass from the family of curves $\psi_1, \psi_2, \ldots \psi_n$ to a similar family,

$$\varphi = F(t, \tau),$$

by an appropriate method of graphic solution. φ thus expressed as a function of time and strain, for all degrees of hardness and all degrees of temperature T, is the complete solution of the problem in hand.

I take pleasure in acknowledging that the greater number of experiments in this paper are due to Mrs. Barus.

Laboratory U. S. G. S., Washington, D. C.

Art. II.—*Kilauea in* 1880; by William T. Brigham.

May 1, 1880, an outbreak from the summit crater of Mauna Loa, in the Hawaiian Islands was reported. Some persons made the ascent and found a fire fountain from the floor of the small crater adjoining Mokuaweoweo, but this soon ceased and no lava escaped from the crater or from any visible rent on the mountain side. This was unusual, and thinking the slight summit eruption was probably a prelude to a more extensive outbreak, I started in June for the Hawaiian Islands taking with me Mr. Charles Furneaux, a well-known artist, that I might be able to preserve for scientific study, should we be so fortunate as to see an eruption, those appearances that the camera does not retain and which are so difficult to describe.

As soon as possible after our arrival in Honolulu we sailed for Hilo and made the ascent to Kilauea. The road had certainly not improved during the fifteen years since I had last

* If c' be the rate of the index for perfectly elastic wires, then $\psi - c't$, and $2c't - \psi$ correspond respectively to the viscous motion and the strain intensity at the time t. The curves ψ will in general be circumflex, passing from an initial tangent c' to an asymptote which is the rate of rotation of the lower end of the wires.

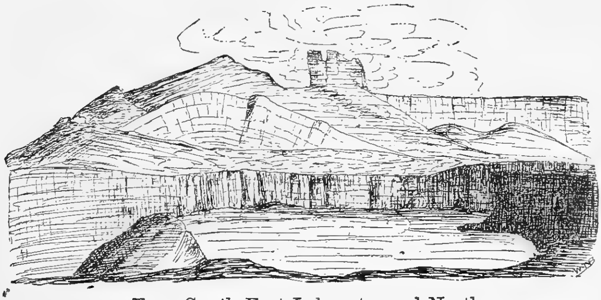
traveled over it, but on the evening of July 24th, 1880, with Mr. R. Forbes Carpenter and Mr. Furneaux, I arrived at the northeast bank of the crater, where we found a very comfortable hotel replacing the grass shanty I had occupied in 1865, while surveying Kilauea. The scene was familiar. Five times had I come to the crater at night on my way from Hilo, and almost as many times while journeying from Kau, but the wonder of the view never dulled, and to-night the fires far away to the southwest were very brilliant, brighter, perhaps, than I had seen them before.

On the morning of the 25th, we descended into the crater by the usual path leading under Waldron's Ledge. The temperature on the upper bank was 58° Fahr. and the steam from the many cracks parallel with the crater walls seemed more abundant than usual. These massive walls had been much broken, and huge fragments of ancient lava had been tumbled down in the path, making the descent much easier, and also indicating more clearly than I had ever seen before, the way in which this vast crater has attained its present proportions. The original walls may have been of small extent, but the jar of earthquake shocks cracks the not firmly united layers of lava which compose the bounding walls, and finally throws down to the floor blocks of lava in size proportioned to the strength or frequency of the shocks; then the next period of activity in the lava-supply sends over the floor streams of lava which float or melt these blocks, thus clearing away the talus. It is difficult to understand how the melted lava can raise and float the much more compact old lava, but I have seen it done more than once and the impression the sight conveyed was of a black hand gently passing under the heavy block and raising it or carrying it along. In the same way lava has insinuated itself beneath stone walls built to bar its progress and lifted and overthrown the futile barrier. So extensively has this process been at work in Kilauea that my survey of the crater, made with great care in 1865 and six years later adopted by the Trigonometrical Survey of the Hawaiian Government and republished on their official map, is already antiquated, except in a few points, ascertained by my monuments still standing; the whole boundary has perceptibly changed, and I consider Kilauea nearly five per cent larger than it was eighteen years ago.

The change visible on the bottom of the crater was even greater I was provided with an excellent barometer, by the kindness of my friend Mr. Carpenter, and found by it that while the bottom of the crater, at the base of the outer wall where first reached in our descent, was 650 feet below the Volcano House, the central portion was only 300 feet, or, in other words the floor was raised in the general shape of a flat dome

350 feet high. Nor was this hill of lava simply the overflow of the lakes whence the lava runs in frequent outbreaks; the mass was partly composed of these numberless little overflows, but the great mass was evidently elevated in the centre and the cracks every where indicated that this elevation was not a slow cumulative action but had been, at intervals, greatly and irregularly accelerated.

In 1865 the floor of the crater was very irregular, full of caves and intersected by great cracks, but its general surface was nearly horizontal. A few years later the floor fell in over about a third of its area* and the caves and cracks were alike obliterated, a funnel-like depression remaining with but slight signs of fire at the bottom. The action however continued until the funnel was not only filled up but the overflow from it reached the outer walls of Kilauea, and then, for a while, the action decreased and the lava cooled. A renewal of activity floated this crust as is indicated by occasional outflows at the edges, and so the intermittent action had in 1880 formed a tolerably regular dome surmounted by four lakes † of an average diameter of a thousand feet each. The walls of these lakes of fire were much broken and changing daily. They were elevated in places far above the contour of the dome, and from the action of heated vapors, were decomposed until their layered structure was plainly visible at a distance by the bands of brilliant colors not unlike those of the clay cliffs at Gay Head on Martha's Vineyard. Emerald-green, vermilion, blue and indian-yellow, irregularly distributed, indicated either very little homogeneity of the masses or uncertain action of the sulphurous and acid vapors.



From South East Lake—toward North.

It was very easy to see what tumbled down these fantastic cliffs, for the molten mass within the lakes was most active near the edges and under the banks which were undermined horizon-

* See plan, Mem. Bost Soc. Nat. Hist., vol. i, p. 572.

† The latest (southeast) began to form May 15th, 1880.

tally to the extent of fifteen or twenty feet by the white-hot, restless waves. From the under surface of these over-hanging shelves depended long and flexible skeins of what seemed to be volcanic spun-glass, or Pele's hair, lapped by the white waves, and seeming, in the glare in which they swung, to be hot to transparency. These pendents were very numerous, often a foot in diameter and six to ten feet long, fibrous as asbestos, and very flexible. Although they were one of the most remarkable appearances at the southeast lake, it was nearly half an hour before I had any direct evidence of the process of their formation. Occasionally surface explosions took place and the viscous fragments, thrown violently against the roof above, spun out in falling back a glass thread, sometimes several from each lump, the fragment being sometimes as large as a man's head. An attraction, probably electrical, as the compass needle is strongly agitated in the vicinity of the currents from the lakes, drew together these isolated threads until the hank was formed which floated like seaweed in a falling tide. Although I watched several hours I did not see any of these hanks fall into the lake beneath.

The brittle nature of the banks which were formed by overflows and ejected matter loosely cemented by subsequent overflows or spatters, would admit of any amount of degradation, but how is the elevation to be explained? It was no paroxysmal force that raised these cliffs some two hundred feet. Leopold von Buch, that most determined advocate of the Elevation theory of Volcanic Mountains, would have been satisfied that his theory alone could explain the formation of these as well as of the dome in Kilauea of which these cliffs were the crown. A longer stay at the crater, however, gave a more satisfactory explanation. The action in these fire lakes or pools, as has often been mentioned is very irregular and intermittent, often apparently ceasing on one side until the crust there is cool and hard; it then breaks out again from beneath this new crust turning it back like the lid of a box against the bank to which it may be soldered by the molten spatters, or, as is more frequently the case, the crust is raised *en masse* and where it touches the superincumbent cliff, carries this up with it and sometimes topples it over on to the outer part of the wall. In this way I believe the cliffs seen in the sketch, and the whole bottom of Kilauea, nearly three miles in diameter, have been floated up by degrees. If the action was constant the lava would break out along the edges of the swelling plain, as indeed it does when the inflow of lava is long continued, and the surface would become a general level by the accumulation of running lava in the lowest places. But in fact, after a certain amount of lava has flowed up through the throats whose posi-

tion is marked by the surface lakes just mentioned, enough it may be to raise the cool but somewhat flexible crust a few feet in the middle, the supply ceases; the liquid which has permeated all the cracks and fissures in the overlying crust, as the lava on a larger scale injects dikes in the earth's crust, cools and becomes solid, to be in turn raised by a new influx of lava from beneath. Each layer will be thicker near the source and will thin out as the distance therefrom increases, and this is what the cracks and chasms in the dome show so far as one can get into them. The successive layers are very irregular; one not far, perhaps two hundred feet from the outer lake, was six feet thick and contained on a rough estimate ten thousand cubic yards of vesicular lava; next to it was a layer not quite two feet thick and diminishing at a distance of two hundred yards to less than half a foot.

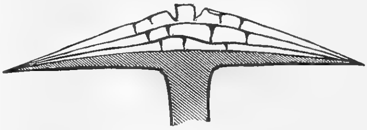


Diagram of elevation.

After examining Kilauea by daylight, I procured lanterns and returned to the lakes about nightfall, traversing the bed of the crater while the daylight lasted. A guide (so-called) who was at the Volcano House, and who went with us that morning, refused to descend after dark, and the hotel keeper put every obstacle in our way; but I had often been there by night before, and my familiarity with the external action of this volcano made it quite safe to pass over any part of the terrible waste in the flickering, lurid light of the earth-fires, and it is only at night that the Halemaumau can be seen in all its splendor. In some respects also it is a safer journey by night than by day; for example, on our way down we crossed a low dome which gave no signs of fire except a clinking sound and a slight bluish vapor common enough in the vicinity of the lakes; the ground was so hot, however, that we crossed it rapidly to save our shoes; on our return about midnight we found that our path had led over a mound wholly injected with a network of molten lava filling the cracks not two inches from the surface, and which, now plainly visible in the darkness, was a startling as well as a beautiful sight. In the daylight the hot lava looks like black tar, and I have several times had to pull my companions from the spot where they might be standing unconscious of the silent black monster which was almost biting their feet, for it was almost invisible on the equally black floor.

In all of my previous visits the bank of the active pool had been at least twenty-five feet above the lava surface, but now we were able to approach the southeast lake nearly on a level and the effect was much grander than usual. I have spent at

various times as many as ten nights in the crater on the banks of this and other similar lakes, and have noticed blue and green flames playing over the cracks in the surface, but these seldom lasted longer than a few moments, and were not confined to any locality. Now, on the contrary, on the top of a huge hummock which seemed to have been broken from the bank, was a cluster of blow-holes from which escaped constantly a large volume of gas which burned with a bluish-green flame well shown in Mr. Furneaux's painting of the lake made on this visit. These jets were burning in the morning, and twelve hours after their volume was apparently unaltered. The pressure evidently varied but slightly, and any increase in pressure did not seem to correspond to greater activity in the molten lava. With suitable apparatus it would have been possible to have collected this gas before it was consumed. Its escape caused a noise similar to that of a steamboat blowing off steam. The mention of steam leads me to express a wish that those geologists who see in steam the prime cause of volcanic action, could have been here, and have studied an eruption of the Hawaiian volcanoes. A pailfull of water thrown into the southeast lake would have made more steam than was present all the time we stayed in the crater. It is difficult to mistake a steamy atmosphere for a very dry one, and then if steam was present in any quantity in the gaseous exhalations of Kilauea, the cold winds from Mauna Loa would soon precipitate it as rain, when in fact this is the dryest part of the island.

The ancient Halemaumau or Everlasting House, where fires have been seen, or whence vapors have escaped from time immemorial, was now replaced, I believe, by the four lakes which occupy the position of that single source. The guide and others insisted that the northeastern of the lakes was the Halemaumau, and without renewing my survey, for which I did not have with me the necessary instruments, I could not positively declare that they were wrong, but I sighted from two of my monuments left from 1865, and comparing with my notes of that survey on my return home, I found the Halemaumau of that day occupied a position nearly southwest of the present so-called Halemaumau, or in the midst of the present four lakes, so that no one of them is entitled exclusively to that name sacred to the ancient worshipers of Pele.

Among other changes the southern sulphur bank had wholly disappeared, having been consumed by a local outbreak of lava which occurred a few months before our visit. The other deposit of sulphur on the northern side near the hotel seemed smaller, and the impression conveyed was of a much smaller amount of sulphur in and around the crater than was found fifteen years before. None of the fine crystals so common then could be found now.

West of the crater on the Kau road, in the region called Umekahuna, are many small cracks which indicate plainly a general and extensive subsidence. Farther to the southwest was a long line of smoke or vapor extending, it may be, to Ponahohoa, where Rev. William Ellis found* marks of a recent outflow in 1823. I had no time to follow the evident line of fissure, and I am not informed that any one has been able to do so since. In March, 1881, an eruption took place in the lateral crater on the southeast side of Kilauea called on my survey Kilauea iki, and properly so called, although popular authority gives this name to Poli a Keawe, leaving this curious pit nameless. The overflow was slight and filled the deep crater about seventy-five feet from the bottom, leaving a glistening, level surface marked with cracks.

As the moon rose about midnight we started for the upper bank and the Volcano House. The brilliant moonlight of the tropics glittered on the metallic lava in cold contrast to the hot fire-light we had just left, and as the shadow of the high ledge fell across our path we had to walk warily and in single file to avoid the cracks our feeble lantern hardly indicated. Once on the path up the wall, we separated, and the most active got home half an hour before the last of the party.

On the 29th of July, having in the meantime made the ascent of Mauna Loa, I returned to Kilauea. In the afternoon I went to the Kau bank, and while Mr. Furneaux sketched Kilauea from the West, I photographed the cliffs of Halemaumau, and then descending two of the gravelly terraces which form the border of the crater on this side, found myself on the brink of

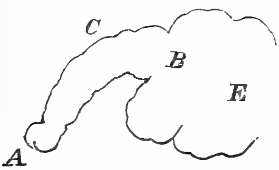
From Kau Bank—toward the East.

a perpendicular cliff beneath which the lava was escaping from several openings situated on the lower edge of the dome. The action was curious, and although the heat was very great at this height of nearly one hundred feet, I managed to watch and sketch it for an hour. The noise here was peculiar; for in addition to the clinking as of shivering glass, usually heard when this black and glassy lava cools, and the puffing or blowing common enough in the lava pools, there was a dull subterranean rumbling as of heavy machinery moving beneath the crater. It was the same noise I had heard during an earth-

* A Tour through Hawaii. London, 1827, p. 203.

quake two days before at Stone's Ranch many miles from Kilauea, and it was not unlike the sound of many looms in a cotton factory. Here there was no earthquake tremor although there is always in and about Kilauea a vibration of the ground very clearly seen when using a compass needle, but seldom noticed otherwise.

The cliff where I watched was not over the lowest part of the crater, but was where the active pools approached nearest to the outer walls, for the dome has a very eccentric apex. The fluidity of the lava as it came to the surface was about that of cream. There is so far as I know no definite scale to which we may refer various degrees of viscidity, and I am compelled to use homely comparisons which have the further disadvantage of being a variable standard. It was white-hot cream when it came out from under the crust, but in the distance of perhaps a foot had changed to a cherry red molasses, while a few feet more transformed the stream into dull red tar. By daylight the color ranges from that of arterial to venous blood, and thence to a slaty blue marking the loss of temperature by chromatic changes. At night all the moving portion is a bright red. A single outlet of small dimensions made much noise blowing, although the gas expelled was invisible. The lava (A in the diagram) issued white-hot, ran a few feet rapidly, then crusted over, retaining its red glow along the edges of the narrow conduit C. At B there was a contraction and the flow stopped for a while; then the fountain at A renewed the supply and the lava ran rapidly from the narrow outlet B, spreading in a broad, thin sheet which did not lose its color until it reached the point E, while the original narrower and thicker stream had formed a crust and become black in less than a quarter of the distance. In places the lava met upward inclines, then the cooling but still flexible crust made a dam and carried the fluid part up and over a rise of some feet. The little lava spring was an epitome of a full lava flow and was more instructive than the immense fiery floods that from time to time break out from these volcanoes and flow for many miles. Later in the evening this insignificant flow became more active, covering twenty acres and giving more light than the lakes themselves.



Over one of the steam cracks near the Volcano House on the northeastern bank, and in close proximity to what remained of the sulphur bank, had been built a very rude steam bath. A hut of ample dimensions, a box with a stool in it, and loose boards to fit around the neck of the bather, with a wooden sluice from the steam crack to the box and a slide to regulate

the admission of steam, constitute the entire apparatus. Seated in the box late that evening, in utter darkness, while the attendant had gone outside with the lantern to get a pail of cold water, I heard, in the stillness, sounds deep down in the steam crack, rumbling and hard noises totally unlike the soft hissing or sputtering of the steam. Fearing that my imagination lent strength if not being to these sounds, I went to a crack outside and, at the risk of pitching in head-first, listened carefully. The same noise was heard distinctly, not unlike that of an earthquake, but feebler.

ART. III.—*Recent Explorations in the Wappinger Valley Limestone of Dutchess County, N. Y.;* by W. B. DWIGHT.

No. 6.—*Discovery of additional fossiliferous Potsdam Strata, and Pre-Potsdam Strata of the Olenellus group, near Poughkeepsie, N. Y.*

THE last one of the preceding papers of this series* announced the discovery of fossiliferous strata in arenaceous limestone of the Potsdam group on the Smiley farm, in the very outskirts of the city of Poughkeepsie; and also the extension of these strata along a line of faulting with the slates of the Hudson River group, to a point on the river three miles south of the city. It was also stated that these strata form the western margin of a belt of limestone from 3000 to 6000 feet in width, which is here the most western of three parallel and contiguous limestone belts, separated by Hudson River shale; and that there was no evidence in my possession to show how much of this breadth was occupied by the Potsdam, and how much possibly by Calciferous and Trenton rocks, except the presence of a single narrow ledge of fossiliferous Trenton on Kimlin's farm very near the eastern edge of this belt.

Further researches, during the spring of 1886, resulted in making known the presence of a proportionally large extent of Potsdam strata in this particular limestone belt, and in other localities in the more northern part of the county. A ledge of Potsdam containing *Lingulepis pinniformis* was found about a hundred feet east of the public road on the farm of R. J. Kimlin, and a little north of his barn. This ledge lies only a short distance northwest of the Trenton ledge on Kimlin's farm, previously mentioned, and whose exact position is indicated on the stratigraphic map of this locality published with my preceding paper. The indications would point to a possible fault here between the Potsdam and Trenton.

* This Journal, February, 1886.

A few days later, a very important outcrop of Potsdam, rich in fossils, was found on the Spackenkill Creek road, and in the same belt of limestone. This road runs nearly east and west, consequently crossing the belt; it is one mile and a half south of the fossiliferous locality at the Driving Park (Smiley's farm). The fossiliferous Potsdam ledge is at the junction of the Spackenkill road with a short road leading to Varick's farmhouse, and is about one mile east of the western edge of the belt, that is, of the line of fault between the Potsdam and Hudson River group previously described. It is thus situated near the eastern edge of this limestone belt.

The distribution of these fossiliferous localities, as now known, suggests the probability that almost the entire breadth of this limestone belt (in most parts more than a mile), from its western margin nearly to its eastern margin, is Primordial rock; and this continuously southwest to the Hudson River, where it terminates with a river-front, oblique to its line of strike, of about one mile and a half, between Mallory's Dock and the mouth of Casper Creek. The lithological features favor, rather than oppose this supposition. It also seems probable that the eastern edge of this primordial is a line of fault, parallel with the strike, against Trenton strata in some places, and perhaps the Hudson River shales in others; but more research will be needed to determine this. At one spot in this Spackenkill locality a thin layer was found crowded with well-defined fossils. These consist of excellent specimens of *Lingulepis pinniformis* and the kindred species as found at the Smiley farm, commingled with masses of glabellas, free cheeks and pygidia of two species of trilobites which I have not yet identified at the Smiley locality. These trilobites are species previously found by Mr. C. D. Walcott in Saratoga county, N. Y., and described by him (as Calciferous fossils,) in the Thirty-Second Annual Report of the New York State Museum of Natural History, under the names *Conocephalites calcifera* Walcott, and *Bathyurus ornatus* Billings. They are now however, referred by Mr. Walcott to the Potsdam strata, and on page 21 of Bulletin 30, of the United States Geological Survey they are listed by him in the Saratoga Potsdam fauna under the names *Ptychoparia calcifera*, and *P. Saratogensis;* closely related respectively to *P. Wisconsensis* and *P. Oweni*. The fact of the correlation of these Poughkeepsie strata with the Saratoga County Potsdam is thus established. There is another locality of Potsdam rock along the summit of the most eastern one of these three belts of limestone in this vicinity. It was mentioned as a probable but not a certain fact, in a note to my preceding paper; but I feel now quite certain of the fact. It would appear as if the Potsdam here presented a "strike-fault"

with the Trenton, a finely fossiliferous ledge of which closely adjoins it on the east side of the ridge.

Later researches in the limestone more to the northward developed an additional locality quite fossiliferous, and possessing some very interesting features. It is about half way between Pleasant Valley and Salt Point, and very near Schoolhouse No. 12, just at the point where a branch road from the main road towards Wappinger's Creek, crosses the limestone ridge with a sharp turn to the north. Here, in the cut along the road and in Mr. Paul Flagler's fields on either side of the road, can be found excellent specimens of *Lingulepis pinniformis*, and of an interesting Obolella which is apparently a new species. Specimens found here are quite finely preserved. This locality is seven and a half miles northeast from Poughkeepsie, and about the same distance northerly from the Smiley locality. This ledge can be traced for half a mile or more to the north of the schoolhouse, though it has not shown fossils much in this direction; at Wallace's quarry, however, a mile to the northeast, fossiliferous Potsdam again crops out at the eastern base of the high ledge of Trenton and Calciferous limestone close to the farmhouse. This increases very much the difficulty of solving the previously difficult problem of the stratigraphy of Wallace's very interesting quarry. While my earlier examinations of the limestone between Salt Point and Pleasant Valley have produced undisputable evidence of the presence there of Trenton strata, and of those which I have considered to belong to the Calciferous. it is now proved that the Potsdam is also present there; there are reasons for believing that it may be very extensively represented in this portion of the belt.

The existence of Potsdam strata of at least the Saratoga County horizon, in considerable abundance, having been thus thoroughly established, the next point of inquiry which would naturally suggest itself, would be as to the possible presence also of pre-Potsdam beds. The width of the limestone belts where the Potsdam rocks have been found in conjunction with those of higher groups, is hardly great enough to lead one to expect to find lower strata; they would be likely to exist, if anywhere, along the margins of the Archæan mountains of the County, where the gneiss is overlain by quartzyte and limestone strata.

On June 24, 1884, up to which date no paleontological evidence of strata even as low as the Potsdam had been found here, Mr. S. W. Ford and the writer made a short trip between two trains to the base of Stissing Mountain, seventeen miles northeast of Poughkeepsie. We desired to take a look at the quartzyte immediately overlying the gneiss, and which for stratigraphic reasons solely, has long been supposed to be Potsdam

and which neither of us had ever seen. In the brief time at our disposal, and under the depression of one of the hottest days of the season, we accomplished scarcely anything more than to lay the foundations for future explorations, by getting some personal knowledge of the topography, and the most accessible points along the rugged sides of this mountain. The quartzyte which we had made our only objective point, we saw only where it was in very compact, homogeneous white masses, and in this, no fossils were found.

During the last week of October and the first week of November, 1886, Mr. C. D. Walcott and the writer made several joint trips of observation through some of the more interesting portions of the complicated stratigraphy of this eastern border of Dutchess County. We spent the first two days of November in paleontological and stratigraphic examination of the strata overlying the gneiss at the southern end of Stissing Mountain. The course which we took after arriving at the Stissingville railroad station, was to follow the valley road running north for a short distance then taking a farm road which, leading westerly, passes along the slopes of the southern extremity of the mountain. We thus traversed the following strata: leaving Hudson River shales at the railway station, we passed over a breadth of limestone, then of bright purple red shales, then, as we ascended the mountain flanks, another breadth of compact bluish limestone, then, at a higher level, quartzose rock, varying between very compact sandstone and quartzyte, and lastly the gneiss composing the bulk of the mountain.

The compact white quartzyte in the more prominent ledges, as before, proved unfossiliferous; but as we struck away from the farm-road into the woods to the north, Mr. Walcott soon found loose fragments of less compact, ferruginous, decomposing, quartzose rock, completely filled with organic remains; among these could be detected glabellas and spines of *Olenellus* with a species of brachiopod and other fossils. In a few minutes we succeeded in finding this fossiliferous rock in place, showing its fossils, which had mostly been injured by the oxydation of iron, in great abundance. Mr. Walcott soon returned to the ledges of the limestone which overlies the quartzyte, where it was exposed in the road, and by discovering there opercula of *Hyolithellus micans*, thus proved that it also belongs to the same horizon as the quartzose strata.

Thus the question of the geological age of the quartzyte of Stissing Mountain, as also that at the base of Fishkill Mountain (which we visited together immediately after leaving Stissing), after many years of uncertain speculation, has been solved; and its solution covers also the knowledge of the age of the

immediately overlying limestone. The credit of the discoveries belongs chiefly to Mr. Walcott whose long and intimate acquaintance with the pre-Potsdam strata was of great service in the search. The fossils discovered have been identified by Mr. Walcott, so far as the present imperfect specimens will permit, as follows:

From the quartzyte:	*Olenellus asaphoides* or *Thomsoni;* probably the former; glabellas and cheek spines. Brachiopods, probably a *Triplesia* and an *Obolella*, sp.?
From the limestone overlying the quartzyte,	*Hyolithellus micans;* opercula, very well defined; rather abundant. *Obolella* sp.?

The strata containing these fossils appear to dip away from the axis of the mountain at a very low angle (from 6° to 10°). But the dip of the adjoining strata increases rapidly with the distance from the mountain, until it reaches the usual angle of the Wappinger Valley strata, that is, from 30° to 45°; and with the increasing dip, it also acquires the general northeast and southwest strike. The Olenellus quartzyte has an estimated thickness of about 160 feet; the Olenellus limestone, of about 75 feet.

Overlying the Olenellus limestone, there are about 60 feet of red shale, and over this about 300 feet of limestone which in turn is surrounded by the prevalent Hudson River shales of the valley. Our first impression was, that the red shale and the overlying limestone belonged also to the Olenellus group. But no evidence of this could be found in fossils. Subsequent study of the similar superposition of strata along the north edge of Fishkill Mountain convinced us that it would not be safe to adopt this view in the absence of paleontological evidence; since the presumption would rather be that the red shales are of the Hudson River group, and the overlying limestones a post-Potsdam rock.

Carrying on our observations for two miles to the southwest, on a line across the strike, we found the strata much faulted, and the quartzyte again brought to the surface. It will require a most careful and laborious search to determine the extent of these newly discovered strata, and their stratigraphic relations to the superior formations.

The succession of strata in the eastern part of Dutchess County (and doubtless also of the entire county), as now probably made complete by these facts of Stissing Mountain, is as follows:

1. The Archæan of Stissing and Fishkill Mountains, and of other elevations.

2. The Olenellus group (Georgia group of Vermont), of quartzose and limestone rocks at the base of the above named mountains.

3. The Potsdam (or Upper Cambrian), well exposed at Salt Point, and a little southeast of Poughkeepsie.

4. The Rochdale group (Calciferous?) This group with its unique set of numerous fossils, yet only very partially described, is the one which in previous papers I have called the Calciferous, because I consider it manifestly most closely related to what has been generally covered by that title. It is evident however that the proper limits of both of the terms "Calciferous" and "Chazy" (as also of the entirely vague title "Quebec group,") are undergoing severe review in the light of recent developments, and that many fossils heretofore assigned to one, may be ultimately found to belong to the other. I have therefore decided to designate these strata provisionally by the name of the locality where their fauna are most richly represented. It must not, however, be inferred that these are the only strata found at Rochdale, for at least the Trenton and the Hudson River strata are also well represented there. The rocks of the Rochdale group are apparently found everywhere in this limestone belt.

6. The Trenton limestone, found richly fossiliferous at Wallace's quarry, Salt Point, at Pleasant Valley, Rochdale, and Newburgh, and generally, in the Wappinger limestone.

7. The Utica slate may also be present in the county, though the fossils found along the banks of the Hudson River and assigned to this group are thought by some experienced paleontologists to belong quite probably to the Hudson River group on the ground of having been actually found in several places mingled with organisms characteristic of the latter group. There are also strong stratigraphic reasons for doubt as to its presence here.

8. The Hudson River shales, prevalent almost everywhere in Dutchess county.

This review of the latest paleontological facts, makes it evident that the strata in Dutchess County are simply the continuation of the strata characterizing the Taconic and adjoining series lying northward. But while proving a grand unity, they indicate also an interesting and unexpected variety of rock-structure.

ART. IV.—*Image Transference;* by M. CAREY LEA, Philadelphia.

BY the term, Image Transference, I propose to denote certain effects produced on sensitive films, effects curious in themselves, and of interest in connection with the subjects of papers which have appeared in the May and June numbers of this Journal.

In those investigations it was shown to be possible to take a film of a silver haloid—chloride, bromide or iodide, and after making marks upon it with sodium hypophosphite to obtain a development of these marks, precisely as if they had been impressed by light, but quite independently of any exposure to light. I now propose to show that it is possible to develop on a film of silver haloid a complete image—a print from a negative for example, without either exposing the silver haloid to light, or to the action of hypophosphite, or subjecting it to any treatment whatever, between the moment of its formation and that of its development. The film of silver haloid comes into existence with the image already impressed upon it.

For this purpose almost any silver salt is selected; citrate, benzoate, tartrate, pyrophosphate, etc., answer perfectly. (Some silver salts, the phosphate especially, undergo a slight reduction spontaneously in the dark; these are less suitable.) A film of the silver salt selected is formed on paper by the ordinary methods, and this is exposed under the negative to a few seconds of sunshine.

The next step is to convert this film into one of silver chloride or bromide, by plunging it for a few minutes into dilute acid. Ordinary hydrochloric acid may be diluted with six times, commercial hydrobromic with two or three times, its bulk of water; the exact strength is unimportant. After a short immersion, the acid is to be washed out, and it only remains to put the film, now consisting of silver haloid, into a ferro-oxalate developer, when the image appears at once. The chloride or bromide of silver into which the salts above mentioned are rapidly converted by the halogen acid, comes into existence with the image already impressed on it at the instant of its formation.

So that although the substance which received the image is completely broken up and destroyed, the image is not, but is transferred in all its details to the new film of silver haloid.

It is therefore evident that the action of light on all silver salts that can thus transfer an image, must be similar in all its essentials to the action of light on the silver haloids. An important conclusion follows, that all such silver salts must be

capable of forming subsalts, else the image could not be transferred. In the case of most silver salts the existence of such subsalts has not before been recognized or even suspected; indeed, if I am not mistaken, the existence of such a subsalt of silver phosphate has been expressly denied. But the image formed by light on silver phosphate can be transferred, therefore subphosphate must exist.

These results have also a very direct bearing on the subject of one of my papers in the last number of this Journal. I there endeavored to show that the photo-salts of silver as obtained by purely chemical means are identical with the products of the action of light on the silver haloids, both with the material of the latent image, and with the visible product of the continued action of light, or rather with the most characteristic constituent of that product. As respects this latter identity, I showed that although the brightly colored photo-chloride could not be obtained by the direct action of light on silver chloride, it could readily be formed indirectly by acting with light on other salts of silver, and treating the product with HCl.

It might be argued that in this proof one link was wanting, viz: proof that the photo-chloride obtained by the action of HCl on silver salts, other than chloride, exposed to light, was of the same nature as that obtained by the action of light directly on silver chloride. The results above described supply that link, if it was needed, and show that the photo-chloride obtained by the action of HCl on silver salts, other than the chloride, exposed to light, has the same capacity for development as has the material of the latent image obtained on ordinary silver chloride.

But this proof itself may be thought liable to an objection. It may be said that as an image was certainly impressed upon the original film, it is not completely proved that the halogen acid had anything to do with the ultimate production of a developed image. The objection would not be well taken, and the experiment may be varied to two ways, either of which eliminates it.

Most silver salts are soluble in nitric acid. After applying the halogen acid, it may be washed off, and the paper may be placed in nitric acid until every trace of the original salt (supposing that any escaped the action of the HCl or HBr) is removed, and until it is absolutely certain that nothing is left in the film but the silver haloid. When this is done, the development, so far from being impeded, is rendered only the stronger and brighter. Certainly therefore the silver haloid is the essential base of the development.

Another very decisive experiment may be made in this way. Paper prepared with tartrate, oxalate or almost any other salt of silver, is to be exposed for a minute or thereabouts to a strong light; (not under a negative). It is then taken into a dark room, and marks are made upon it either with a glass rod or a camel's hair pencil dipped in dilute hydrochloric or hydrobromic acid. After letting the acid act for five or ten minutes, it is to be washed off, the paper plunged into nitric acid, and after again washing, it can be placed in a developing solution when the marks made will appear black on a white ground. This mode of operating gives a very convincing result. The nitric acid treatment may be omitted, but when this is done, the number of salts that can be used is more limited. The four salts first above mentioned give good results, even without the nitric treatment, but some silver salts undergo a spontaneous change in the dark by keeping a short time, such that when they are placed in a developing solution (without exposure to light) they may blacken instantly all over. Silver tartrate is one of the best salts to operate with, though pyrophosphate, citrate, oxalate and some others do almost equally well. Sulphate, antimonio-tartrate, phosphate, nitrite and arsenite do not give good results, except with the nitric acid treatment.

With a salt like tartrate or oxalate the experiment is very striking. The paper imbued with it is exposed to light over its whole surface, it is then taken to the dark room, and simply marked with dilute HCl or HBr and washed. Thrown into a developer, all the marks of the halogen acid quickly blacken, proving, first, that the effect of light is transferred from the one salt to the other; second, that the effect as transferred to the chloride or bromide is far more susceptible of development than it was in the original salt. It seems a not unreasonable explanation of this last-mentioned fact that the greater sensitiveness of the haloid compounds may depend on their power to combine with their own subsalts, so that the reduction may commence with the subsalt, and quickly extend from it to the portion of normal salt with which it is combined; that on the other hand, other silver salts may not share this power of uniting with their subsalts, and are consequently more slowly and imperfectly attacked by the developing solution. This explanation may or may not be correct, but seems not improbable.

A curious fact incidentally presented itself in the course of this investigation: that when paper prepared with silver salts, other than the haloids, was exposed to light, and then marked with HCl, the effect of a short exposure, so far as development was concerned, was as great as that of a long one. A piece of paper was prepared with a given salt by non-actinic light. It

was then placed between the leaves of a closed book with one end projecting. The book was then placed in the light (very faint sunshine), and the prepared paper was gradually drawn out so that different portions received progressive exposures from 400 seconds down to 3 seconds. A number of marks were made with HCl diluted, parallel to the end of the paper, so that to each mark corresponded a different exposure from 3″ to 400″. The papers were then placed in nitric acid, washed and developed. These pieces are before me as I write, and it is impossible to say by the appearances which portion received the 3 seconds, which the 400. The marks are equal in strength on each paper from one end to the other. The salts used were: silver benzoate, tungstate, phosphate, pyrophosphate and tartrate. The short exposure gave a sufficient basis for development, the longer effected nothing more.

The object of this series of papers has been to offer a new explanation of the nature of the latent photographic image, and to show that it consists neither of the normal silver haloid physically modified, nor of a subsalt, but of a combination of normal salt and subsalt. That the subsalt loses in this way its weak resistance to reagents, and acquires stability, thus corresponding to the great stability of the latent image, which, though a reduction product, shows considerable resistance to even so powerful an oxidizer as nitric acid.

Further, that this combination of normal salt and subsalt, which constitutes the material of the latent image, can be obtained by chemical means, and wholly without the aid of light. That the forms of these photosalts, as I have ventured to name them, which correspond to the material of the latent image are either colorless or nearly so, but that other forms, possessing beautiful and often intense coloration, also exist. With the chloride some of these brightly colored forms show a ready tendency to reproduce color, in some cases with well marked and beautiful tints. So that we have here an approach to the solution of the problem of obtaining images of objects in their natural colors from a quite new direction, and probably with better hopes of an eventual complete success than by any of the older methods.

Philadelphia, May 17, 1887.

ART. V.—*Notes on the Lower Carboniferous groups along the easterly side of the Appalachian area in Pennsylvania and the Virginias;* by JOHN J. STEVENSON, Prof. of Geology in the University of the City of New York.

THE division of the Lower Carboniferous into Umbral and Vespertine, as made many years ago by the Professors Rogers, holds good along the easterly side of the Appalachian area certainly into Tennessee. But these groups show notable variations in thickness and in character of the rocks, not only along lines from southeast to northwest but also along the line of strike, or from northeast or north-northeast southwardly. The writer has had opportunity to study these variations somewhat in detail within the southern counties of Pennsylvania as well as in the southwestern part of Virginia beyond New River to the Tennessee line, and to some extent at widely separated localities in West Virginia.

The Umbral within Pennsylvania is, for the most part, a mass of red shales and shaly sandstones and is so well shown as such in the Anthracite region that Prof. Lesley has renamed it the Mauch Chunk. Some thin beds of limestone, first seen near the Maryland line along easterly outcrops, increase westwardly and become important at the last exposures under Chestnut ridge in Fayette County. But the thickness of the group diminishes as the limestone increases, being little more than 200 feet in Fayette,* whereas it is about 1100 feet in Fulton County.

The Vespertine in central and south-central Pennsylvania shows sandstone and shales with occasional streaks of coal. The sandstones vary from fine-grained to moderately conglomerate and the shales are irregular in thickness and character. The variations in thickness are not unlike those of the Umbral, the decrease being from somewhat more than 1300 feet in Huntington County (as determined by Prof. I. C. White) to not far from 400 feet in Fayette County. The topmost member of the group is a calcareous sandstone, the siliceous limestone, which first appears in Huntingdon County (White) and thickens toward the west. This is the "Ligonier paving stone," much used in Pittsburgh and other cities. In the writer's Pennsylvania reports, this is placed as a member of the Umbral, but its relations are rather with the Vespertine.

* The thickness given for Fayette county is barely half that assigned to the group in the writer's report on the geology of that county. The writer is convinced that the upper portion belongs not to the Umbral but to the Lower or Conglomerate Coal Measures.

In comparing the Lower Carboniferous of southern Pennsylvania with that of southwestern Virginia, the great difference in conditions must not be overlooked. Owing to absence of faults within the Cumberland Valley of Pennsylvania (the same with the Great or Shenandoah Valley of Virginia) and to the presence of great folds on the westerly side of that valley, the first outlier of Lower Carboniferous rocks is on Licking Creek Mountain in Fulton County 33 miles from the Archæan of South Mountain; the next is on the west side of the same county 8 or 9 miles farther west, and is separated by an interval of 30 miles from the next exposure on the border of Somerset county.

But such is not the condition in southwest Virginia. The Draper Mountain fault in Pulaski County shows Umbral and Vespertine on the downthrow side at not more than 12 miles from the Blue Ridge Archæan; the Price Mountain faults in Montgomery County show the same groups at not more than 15 miles from the Archæan; the Walker Mountain fault shows Umbral and Vespertine on its downthrow side from Smyth County to many miles beyond New River; while the Saltville fault* shows the Lower Carboniferous from the Tennessee line to the edge of Giles County. So there are good and extensive exposures, giving satisfactory sections at 12, 15, 21 and 23 miles from the Archæan, while the outcrop on the side of the great coal-field is reached at barely 15 miles farther N.N.W. The line of the Saltville fault is very nearly equivalent to that of the most easterly outcrops in southern Pennsylvania; and for purposes of comparison, it will be taken as such.

The conditions observed in the easterly outliers within Pennsylvania do not change rapidly toward the south. Prof. W. B. Rogers's assistants obtained the following measurements near Westernport on the Potomac:†

Umbral.

Shale and sandstones	650′
Limestone	4′ 6″
Shale and sandstone	186′

Vespertine.

Siliceous limestone	79′
Sandstone and conglomerate	200′

No very noteworthy change in the character of the rocks occurs until within 75 miles of the Tennessee line; for Brushy

* For descriptions of these faults, see the writer's paper in this Journal for April, 1887.

† Report on Geology of Virginia for 1839, p. 89 and 91. I have rearranged the section so as to throw the Siliceous limestone into the Vespertine, the Formation X of Prof. Rogers, instead of leaving it in his Formation XI, the Umbral.

Mountain, on the northerly side of the Saltville fault, shows in Bland County the Umbral consisting of red shales and sandstones, and the Vespertine made up of sandstones, shales and coal beds, with an impure siliceous limestone at the top. The Umbral has not much less thickness than in Bedford County of Pennsylvania, but the Vespertine is decidedly thinner. The same structure appears along the Walker Mountain exposure, and even in that north from Draper Mountain in Pulaski County where the siliceous limestone at the top of the Vespertine is distinctly shown in the railroad cutting at only 4 miles east from Max Meadows station. This is interesting, as the locality is but 12 miles from the Archæan, whereas in Pennsylvania this limestone is barely recognized in Huntingdon County at 40 miles from the Archæan of South Mountain.

The Umbral contains occasional streaks of coal in Pulaski and Bland Counties, but these are wholly unimportant. The especial economic interest of the Vespertine lies in its coal beds, which attain considerable importance near New River along the Walker and Price Mountain faults in Montgomery, Pulaski and Wythe Counties, as well as along the Saltville fault in Bland and Smyth Counties. These have been described by Rogers, Lesley, Fontaine and the writer, so that only an incidental reference to them is necessary here. Not less than seven or eight beds exist, but only three appear to become valuable. All are practically worthless except in the vicinity of New River, where a semi-bituminous coal is obtained, which is esteemed for domestic use, despite the ash, which varies from 11 to 39 per cent, as appears from the analyses published by Mr. A. S. McCreath.*

The fault of Walker Mountain quickly lessens beyond the westerly line of Wythe County and thence to Tennessee no Lower Carboniferous rocks are shown between the Saltville fault and the Archæan. A great change in those rocks begins in Smyth County. The shales of the Umbral lose little of their thickness, but limestone appears toward the bottom and increases in thickness so rapidly that within 15 miles it has become the prominent feature of the group. Meanwhile the sandstone and shales of the Vespertine lose their importance ; the coal beds are reduced to mere streaks and the calcareous sandstone at the top becomes a calcareous shale or disappears. This changing condition continues until, at Mendota in Washington County, about 15 miles from the Tennessee line, the Vespertine sandstones and shales have practically disappeared, while the Umbral limestones have increased vastly in thickness, though not at the expense of the shales. The section at Mendota is :

* The Mineral Wealth of Virginia, &c., 1884, pp. 130–131.

Umbral.

Shales and sandstones with thin limestones	800′
Limestones and calcareous shales	1470′
Limestones, cherty, with calcareous shales	655′

Vespertine.

Concealed	40′

In coming northward from Tennessee, one finds much difficulty in attempting to draw a line between Umbral and Vespertine; the writer in his memoirs on southwestern Virginia used the classification adopted for Tennessee by Prof. Safford. But there is no room for doubt to one coming southward; for the Pennsylvania Vespertine is easily recognized in the coal-bearing series of Montgomery, Pulaski, Wythe, Bland and Smyth Counties of Virginia. One can follow this group along the side of the Saltville fault, as the thickness diminishes, until the whole mass of not less than 700 feet has its representative in the concealed interval of the Mendota section, in which a thin bed of coal is said to exist. Whether or not any trace of this group remains at the Tennessee border could not be determined from the exposures.

Northwestward, on lines of exposure bounding or within the great coal field, equally notable variations exist. Near the Pennsylvania border, the limestone of the Umbral increases in importance westward until under Chestnut ridge it is certainly one third of the whole mass, which is not far from 200 feet thick. The Vespertine, however, shows little change other than in thickness. Southward from the Pennsylvania line, the first measurement is that by Prof. I. C. White* in Monongalia county of West Virginia: the section in the gap of Cheat River through Chestnut ridge showing:

Umbral.

Shales	295′ to 300′
Limestone	95′ to 120′

Vespertine.

Sandstones with siliceous limestone at the top	125′

As the fold of Chestnut ridge decreases rapidly southward, the next measurement, also by Prof. White,† was obtained in the gap made by the same river through Briery Mountain in Preston County of West Virginia, at about 30 miles southeast from the other. This shows:

* Proc. Amer. Phil. Soc., vol. xx, p. 484 to 488.

† *The Virginias*, July, 1882. I have re-arranged the sections so as to place the siliceous limestone, 105 feet, at the top of the Vespertine.

Umbral.

Shales	370′
Limestones and calcareous shales	226′

Vespertine.

Sandstones with siliceous limestone on top	681′

But the writer found the Umbral shales absent from Rich Mountain in Randolph County, of West Virginia, where the Coal Measures rest directly on the limestone, which is more than 700 feet thick, inclusive of calcareous shale. A thin streak of coal occurs in the calcareous shales here opposite Beverly.

All parts of the Lower Carboniferous increase greatly within a short distance southward from this locality, for in Pocahontas County, of West Virginia, Prof. J. B. Rogers obtained the following measurement of Umbral on Greenbrier Mountain:*

Sandstones and shales	1260′
Limestones and shales	822′
Red shales	50′
	2132′

while the Vespertine is not far from 800 feet thick. The maximum thickness is attained here, for near New River, according to Prof. W. M. Fontaine's measurements,† the undoubted Vespertine, to the top of the coal-bearing series, is barely 500 feet. The writer found the shales and sandstones of the Umbral about 900 feet thick at 15 or 20 miles beyond New River in West Virginia, where they show a few streaks of impure limestone. Thence the many exposures amid the Clinch faults in Tazewell, Russell and Scott Counties, as well as those under the Stone Mountain anticlinal in Wise and Lee Counties of Virginia, show a constant decrease of Vespertine while the Umbral retains its importance, though with reduced thickness. The last examined exposure is in Pennington's gap through Stone Mountain in Lee County, where the section is:

Shales, sandstones and thin limestones	705′
Limestone and calcareous shale	150′
Cherty limestone and siliceous beds	200′
Reddish siliceous beds	150′
	1205′

* Report on Geology of Virginia for 1839, p. 32. The absence of details makes it impossible to determine whether or not the Siliceous limestone is included in the Umbral, Formation XI.

† This Journal, Jan., 1877.

If there be any Vespertine present, it is to be found in the lower part of the reddish siliceous beds. Whether or not any Vespertine exists in Tennessee cannot be determined in the present state of our knowledge. It is certain, however, that the group has thinned almost to nothing, if it have not wholly disappeared before the Tennessee border has been reached along these lines of outcrop.

The Umbral of Pennsylvania, Maryland and the Virginias is equivalent to the Chester and St. Louis groups of the Mississippi Valley, and it may include the Keokuk; while in the Vespertine must be sought the equivalents of the Burlington and possibly of the Kinderhook. Chester fossils are abundant in Pennsylvania and the Virginias in the upper part of the limestone; and that group was recognized in 1869 by Mr. F. B. Meek, during the examination of some fossils collected on Cheat River near the Pennsylvania line. St. Louis fossils are plentiful at many localities in central and southern West Virginia as well in southwestern Virginia.

The facts thus far given seem to afford basis for some conclusions respecting the geography of the Lower Carboniferous periods.

The Vespertine shore-line lay somewhere within the present area of the Archæan; the subsidence was much more rapid in the northeastern part of the Appalachian gulf than it was further west or southwest, the rate gradually diminishing in those directions; for the 1300 or 1400 feet of Huntington County, Pennsylvania, becomes little more than 400 feet in Fayette County of the same State, and about 800 feet in the extreme southeasterly exposures within Virginia beyond New River; and these are much nearer the old shore-line than are those showing the great mass in southern Pennsylvania. Low or marshy land reached westward for a long distance from the Blue Ridge, as well as southward from the northerly shore-line in New York; for thin streaks of coal occur at several horizons within the sandstones of Bedford County, Penn., at 50 miles from the Archæan, while near the New River and its tributaries there are great beds in Virginia at 25 miles and, according to Fontaine, in West Virginia at 50 miles, from the Blue Ridge Archæan.

The whole area under consideration was a region of shallows, except perhaps the extreme southwest corner of Virginia, for no limestone bed occurs except at the top where the Siliceous limestone ends the column. This is first seen, and very thin, on the easterly side of the Broad Top basin in Fulton and Huntington Counties of Pennsylvania at 40 miles from the Archæan; whereas in Virginia it is shown equally thick within 12 miles of the Archæan on the northerly side of the Draper Mountain fault.

Along the easterly outcrop in southern Pennsylvania this group is not merely very thick, but it contains coarse sandstones with not a few beds of conglomerate. But westward and southwestward to southward, the beds become less coarse, the conglomerates practically disappear and the group is represented even in the Draper Mountain area almost wholly by fine grained sandstones interstratified with shales. The variations in thickness along definite lines are probably not so great as the measurements at various points appear to suggest; on the contrary, a comparison suggests that the changes along the southeasterly border were not abrupt until considerably beyond New River. In Smyth County, of Virginia, the change begins, and thence the group thins out so rapidly that it is recognized only with doubt in Washington and Lee Counties, and its existence in Tennessee is at least questionable.

These conditions appear to show that the land area at the east was narrower in southern Virginia than in Pennsylvania and at the same time less elevated; that the streams were shorter and had less rapid fall, so that the detritus brought down by them was less in amount as well as less coarse. It is worth noting that the variations of this detrital group are very like those of the upper Devonian.

Throughout the Umbral, that part of the Appalachian gulf lying within the present boundaries of Pennsylvania, was practically shallows throughout, except for brief epochs, during which thin limestones were deposited. The easterly shore-line in Pennsylvania and Virginia lay along the Blue Ridge, as during the Vespertine, but doubtless much farther toward the southeast; for in the most easterly areas spared by erosion, those in the Anthracite region of Pennsylvania and those in Montgomery and Pulaski Counties of Virginia, the Umbral rocks are fine clayey shales or argillaceous sandstones and clay beds, which contrast sharply with the well marked and often conglomerate sandstones of the Vespertine in Pennsylvania. No limestone is shown in Virginia along the Walker or the Saltville fault eastward or northeastward from the line of Smyth County; nor is any seen in northern Virginia, aside from petty streaks, east from the North Fork of the Potomac River.

The Umbral limestone is shown in Fayette County, of Pennsylvania, as well as in the adjoining county, Monongalia, in West Virginia. It can be followed along an almost continuous outcrop through Preston, Tucker, Randolph, Pocahontas, Greenbrier, Monroe and Mercer Counties, of West Virginia, into Tazewell, Smyth and Washington Counties, of Virginia. The mass increases along these outcrops from a few feet in Fayette County, of Pennsylvania, to more than 2100 feet in

Washington County, of Virginia. This space of limestone and calcareous shale marks the course of deep water during the long early part of the Umbral, which seems to be represented by very little material of any sort in the greater part of Pennsylvania.

The limits of this area appear to be well-defined in southwestern Virginia. Eastward the great mass of limestone and calcareous shale disappears within 8 or 9 miles, for not a bit of it was seen along the Walker Mountain fault, nor is there any along the Saltville fault in Bland County. At 50 miles toward the west, in Pennington's gap through Stone Mountain, the whole thickness of calcareous beds is barely 400 feet, and a great part of that hardly deserves the name of calcareous shale. This certainly indicates a shore not far away in Kentucky, and leads at once to the conclusion that the Appalachian gulf was greatly narrowed along the present southern line of Virginia. The area of deep water extended almost north and south until near the southern boundary of Virginia, where it was turned slightly toward the southwest, and there its width could not have exceeded 75 miles. Its direction was more nearly coincident with that of the Cincinnati axis than with that of the Blue Ridge region.

The Lower Carboniferous was closed by a gradual silting up of the gulf, a preparation for the Upper Carboniferous. Throughout the whole area of Pennsylvania, Maryland, West Virginia and Virginia, this upper division of the Umbral is a mass of shales and sandstones with rare and thin streaks of impure limestone in the more westerly portions of the area. In many localities the passage from the Lower to the Upper Carboniferous is indefinite, as the lower plate of the Quinnimont group or Lower Coal Measures is absent; but for the most part the plane of separation between the two divisions of the Age is sufficiently distinct.

Art. VI.—*The Theory of the Wind Vane;* by George E. Curtis.

The common weather-cock, or wind-vane, is no doubt the oldest, as well as the simplest, of meteorological instruments. In its earliest use, as a popular indicator of the weather, erected at the summit of a flag staff or a church tower, or, in New England, forming the usual apex of the town liberty pole, the vane assumed the form of a cock, a fish, a trumpeter, or other ornamental device; but, with its application to accurate

meteorological observations, these forms were replaced by simple plane plates, discs, or arrows, designed solely with regard to the mechanical action of the wind upon them.

The form in general use at present is that of an arrow with a double or spread tail. The first reference I find to the construction of a vane of this design is by the elder Parrot, (Voigt's Magazin, i, 1797). In order to diminish the continual oscillations to which the vane is subject during variable winds, he made a vane of two thin plates joined at one end at an angle of about 45°. This was used by the younger Parrot, in his well known expedition to the Caucasus in 1811, with Engelhardt. Similar vanes were soon introduced in other countries, and by 1840 were in common use by English meteorologists. With respect to the advantages of their use, Jelinek, writing in 1850, makes the following statement: "The English seek to obviate the disadvantages of the complete rotations by making the vane of two plane surfaces set at an angle to each other of generally about $22\frac{1}{2}°$. They say that thereby the oscillations are smaller, and the complete rotations less frequent." Stating that experience shows this to be true, Jelinek adopted the same form for a self-recording anemoscope, designed as an improvement on that constructed for the Austrian meteorological service by Dr. Kreil in the preceding year, which, consisting of a single plane circular plate, had occasioned much difficulty by its frequent complete rotations.

While the spread vane has thus grown in favor, the angle of the wings has gradually been reduced. Starting with an angle of 45°, as made by Parrot in 1800, the angle in 1850 was generally $22\frac{1}{2}°$, and at present even a smaller angle is frequently used. In practice the surfaces are made with a slight curvature, so that the actual angle made by their tangents increases from zero at the vertex, to 30°, or more, at their extremities. Voigt's Magazin, in which Parrot's description of his vane appeared, is not accessible to me, and his reasons for adopting 45° are not given by reviewers. Similarly, I have found no explanation of the reason for adopting any of the smaller angles subsequently used. The following analysis has therefore been made, in order to find definitely what advantages the spread vane possesses, as compared with a straight vane of the same length and shape, and at what angle the wings should be set to secure the greatest efficiency.

The wind vane, its surfaces assumed to be plane, is a case of a body immersed in a fluid current, whose resultant pressure is normal to the exposed surface, and proportional to some function of the angle of incidence. If α be the angle between the surface normal and the perpendicular to the direction of the current, the old theory of the resistance of fluids made the re-

sultant normal pressure upon the surface proportional to $\sin\alpha$. This was based upon the theory that the amount of fluid impinging on a unit of surface is proportional to $\sin\alpha$, and the normal component of pressure exerted also proportional to $\sin\alpha$: or again, the velocity of the fluid resolved perpendicularly to the surface being $v \sin\alpha$, the resultant force exerted against the surface must be proportional to $v^2 \sin^2\alpha$. But all this reasoning is now known to be worthless. Experiment shows that the resistance is much more nearly proportional to the $\sin\alpha$ than to its square. Colonel Duchemin* was one of the first to give a more accurate formula based upon the results of experiments. He found that the pressure on a plane moving obliquely in a fluid may be represented by the following empirical formula.

$$N=P \cdot \frac{2\sin\alpha}{1+\sin^2\alpha}$$

in which P is the resistance to a plane moving normally. Later experiments, made for the London Aeronautical Society in 1872, indicate that for large values of α the observations would be better satisfied by making the denominator $1+\sin\alpha$ instead of $1+\sin^2\alpha$. This change has also received a theoretical confirmation. By the analytical method of Kirchhoff and Helmholtz, Lord Rayleigh has derived a formula for the case of a blade-shaped surface which makes the pressure per unit of area $\frac{\pi\sin\alpha}{4+\pi\sin\alpha}\rho v^2$. For small values of α neither of these formulæ differ much from $\sin\alpha$, and for the purposes of this paper it will be assumed that this latter relation holds good; therefore the normal pressure on the surface of the vane tending to produce rotation will be proportional to the sine of the angle between the surface and the wind direction.

Let $(1+n)$P be the total effective pressure on a *straight vane* when at right angles to the wind, where n takes account of the diminution of pressure on the sheltered side. The value of n varies with the angle of obliquity in some ratio not yet fully known, but, for its first approximation may be assumed, like the pressure on the exposed surface, to be proportional to the sine. On these assumptions the gyratory force tending to restore the equilibrium of the vane will be, for an angle θ between the vane and the wind direction, proportional to $(1+n)$P $\sin\theta$.

For a *spread vane*, let ε be half the angle between the two wings and θ the angle between the medial line of the vane and the wind direction. If θ be less than ε, the wind will act on

* Duchemin: Recherches experimentales sur les lois de la resistance des fluides, Paris, 1842.

both wings in opposite directions, but when θ is equal to or greater than ε, the wind will strike only one wing as in the case of a straight vane. Therefore, to obtain a measure of relative sensitiveness, we must compare the gyratory force acting in each of these two cases with the corresponding force acting on a straight vane. For simplicity, suppose the air between the wings to be unaffected by the wind, as would be the case if the space were entirely enclosed.

1. When $\theta < \varepsilon$. The gyratory force is proportional to $P[\sin(\varepsilon+\theta)-\sin(\varepsilon-\theta)]=P\sin\theta \,.\, 2\cos\varepsilon$, in which, for all ordinary angles of the wings, $2\cos\varepsilon$ may be put equal to 1·9. To compare this expression with $P\sin\theta\,(1+n)$, the expression above given for the corresponding gyratory force acting upon a straight vane, we must know the approximate value of n, which varies with the size and shape of the plate. Experiments on normal planes of small size give values of n ranging from 0·2 to 0·86; for surfaces as large as ordinary wind vanes, the upper limit of n can hardly be as great as 0·5 and probably is less. With this value, the ratio of the gyratory force acting on the straight vane to that acting on the spread vane, when $\theta < \varepsilon$, is

$$1{\cdot}5:1{\cdot}9$$

2. When $\theta =$ or $> \varepsilon$. The wind strikes the exposed surface at an angle $\theta+\varepsilon$ and passes the sheltered surface at an angle $\theta-\varepsilon$. The total gyratory force, therefore, will be

$$P\sin(\theta+\varepsilon)+nP\sin(\theta-\varepsilon).$$

Comparing this expression with $P\sin\theta+nP\sin\theta$, the corresponding gyratory force upon a straight vane, the first term is seen to be larger, and the second term smaller, than the respective terms of the latter formula.

If 0·5, the maximum value of n, be substituted in these formulæ, the difference between the two forces will be

$$u=\tfrac{1}{2}\sin\varepsilon\cos\theta-\tfrac{3}{2}(1-\cos\varepsilon)\sin\theta,$$

which is the excess of the force upon the spread vane over that upon the straight vane. For all values of ε less than 41·°4 this excess is positive and has its greatest* value when $\theta=\varepsilon$; with the increase of θ, the excess diminishes and becomes 0 at different points depending on the value of ε, thus

for $\varepsilon=10{\cdot}^\circ$ the excess vanishes for			$\theta=75^\circ{\cdot}3$
$\varepsilon=20{\cdot}$	"	"	$\theta=62^\circ{\cdot}1$
$\varepsilon=30{\cdot}$	"	"	$\theta=51^\circ{\cdot}2$
$\varepsilon=41{\cdot}4$	"	"	$\theta=41^\circ{\cdot}4$

* By an analytical investigation of the nature of u considered as a function of the two independent variables, θ and ε, it appears that this function has no critical value for ranges of ε and θ between 0° and 90°; but the greatest positive value of u (not a critical value) will occur when $\theta=\varepsilon$, the limiting value of θ under the present case.

For a smaller value of n, the excess would vanish at larger values of θ.

Consequently, for all moderate values of ε and θ when $\theta < \varepsilon$, as well as when $\theta < \varepsilon$, the gyratory force acting on the spread vane is greater than that on the straight vane.

If a perfectly sensitive vane be defined as one that instantly responds to the slightest change in the direction of the wind, that vane upon which the winds exert the greatest gyratory force will be the most sensitive, supposing the vanes all have the same friction. The increased sensitiveness accruing to the spread vane from its greater gyratory force is diminished and, for large values of ε, may be quite overcome by its greater lateral friction, due to that component of the wind pressure which passes through the axis transversely. This component is proportional to $\sin^2 \varepsilon$, nearly, and so its effect, which is small and negligible for small values of ε, increases rapidly and becomes an important factor for values of ε greater than 20° or 25°. This lateral friction, therefore, constitutes a condition requiring the angle between the wings to be small. A further indication as to the angle at which the wings should be set for maximun sensitiveness is found by an analysis of the expressions given above for the gyratory force.

1. When $\varepsilon =$ or $> \theta$. Place $\varepsilon = \theta + \alpha$; then

$$2 \sin \theta \cos \varepsilon = 2 \sin \theta \cos (\theta + \alpha).$$

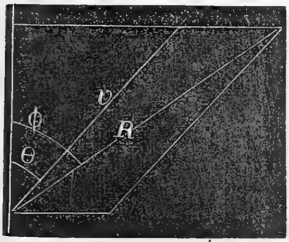
Noting that $(\theta + \alpha)$ must always lie in the first quadrant, this expression has its greatest value when $\alpha = 0$, i. e. when the half angle of the wings is not larger than the angle of the wind's deviation.

2. When $\varepsilon < \theta$. Examining the expression for gyratory force, $\sin (\theta + \varepsilon) + n \sin (\theta - \varepsilon)$, to find a critical value, it appears that the function is a maximum when $\tan \varepsilon = \dfrac{1-n}{1+n} \cot \theta$.

Making $n = \frac{1}{2}$ as before, $\tan \varepsilon = \frac{1}{3} \cot \theta$. For all values of θ up to 30°, this makes the corresponding value of ε to be greater than θ, which for the present case is an impossible value; but for this range of θ, from $\theta°$ to 30°, the *greatest* value of the function (not a *critical* value) will occur when $\varepsilon = \theta$. For values of θ above 30°, the value of ε giving a maximum diminishes downward from 30°, and for $\theta = 90$ becomes 0. Consequently the best values for ε for deviation of the wind below 30° will hold good also for deviations greater than 30°. The conclusion, therefore, is that, for maximum sensitiveness, the half angle of the wings should be the average angle through which the wind makes sudden deviations, this average being taken from 0 to 30°.

The question of the relative stability of a spread and straight vane remains to be discussed. That the continual oscillations of the wind vane are diminished, was the advantage claimed

by Parrot for his spread vane, and has been the justified claim of his followers. Given two vanes of the same moment of inertia, for slowly shifting winds, the oscillations of the spread vane will be smaller than those of a straight vane, for, being more sensitive, it responds more quickly to any gradual change in wind direction, and, therefore, has a less amplitude of oscillation, and will sooner come to rest. When the wind suddenly changes direction through a considerable angle, the straight and spread vanes start out with the same angle of deviation from the new direction. The following analysis shows that, in this case also, the spread vane comes sooner to rest. If v be the velocity of the wind, r a constant depending on the length of the vane, θ the angle between the direction of the wind and the axis of a straight vane, the resultant relative velocity, R, of the wind and the vane will be the third side of a triangle of which two sides are the velocities of the wind and vane, and $90°-\theta$, their included angle.



Whence $R^2=v^2+2v\,r\frac{d\theta}{dt}\sin\theta+\left(r\frac{d\theta}{dt}\right)^2$, $\frac{d\theta}{dt}$ being negative or positive, according as the motion of the vane is with or against the wind. This resultant makes an angle φ with the vane such that

$$R\sin\varphi=v\sin\theta+r\frac{d\theta}{dt},$$
$$R\cos\varphi=v\cos\theta;$$

The effective force tending to turn the vane, which is proportional to $v^2\sin\theta$ when the vane is at rest, becomes $R^2\sin\varphi$ when the vane is in motion. Considering the motion when θ and $\frac{d\theta}{dt}$ are so small that we may neglect the square of $\frac{d\theta}{dt}$ and the product, $\sin\theta\frac{d\theta}{dt}$,

$$R^2 \text{ becomes } v^2, \text{ and } \sin\varphi=\sin\theta+\frac{r}{v}\cdot\frac{d\theta}{dt},$$
$$\text{Whence } R^2\sin\varphi=v^2\left(\sin\theta+\frac{r}{v}\cdot\frac{d\theta}{dt}\right).$$

Let I be the moment of inertia of the vane around its axis, ρ the air density, A the surface of the vane, $f_0(P)$ the pressure of a wind of unit velocity on a unit surface under a standard density of the air ρ_0, and r the distance of the point of applica-

tion of P from the axis. Then the differential equation of motion for a straight vane will be

$$\frac{d^2\theta}{dt^2}+Kv^2\left(\sin\theta+\frac{r}{v}\frac{d\theta}{dt}\right)=0$$

where $K=\frac{\rho A f_0(P)\,.\,r}{I}$.

When θ is small, $\sin\theta$ may be replaced by θ, and simplifying the constants by making $Kv^2=\omega^2$, and $Krv=2k$ the equation becomes

$$\frac{d^2\theta}{dt^2}+2k\frac{d\theta}{dt}+\omega^2\theta=0.$$

This is the equation of a circular pendulum in a resisting medium where the resistance varies as the velocity. The general integral of this equation takes three forms according as $k^2-\omega^2$ is positive, negative, or vanishes; a numerical evaluation shows that it is always negative, for which case, the integral becomes

$$\theta=ae^{-kt}\left\{\cos ht+\frac{k}{h}\sin ht\right\}$$

where a is the greatest value of θ and $h^2=\omega^2-k^2$.

For a *spread vane*, where the half angle of the wings is greater than the deviation of the wind, the wind acts on both wings at once in opposite directions, and the resultant pressure will be

$$\sin(\varepsilon+\theta)+\frac{r}{v}\frac{d\theta}{dt}-\left[\sin(\varepsilon-\theta)+\frac{r}{v}\frac{d\theta}{dt}\right]$$

in which $\frac{d\theta}{dt}$ is to be taken with opposite signs in the two terms, and the expression reduces to

$$2\sin\theta\cos\varepsilon+2\frac{r}{v}\frac{d\theta}{dt}.$$

Using the same notation as in the previous case, and making $2\cos\varepsilon=1{\cdot}9$, which is approximately true for all ordinary cases, we have the equation

$$\frac{d^2\theta}{dt^2}+4k\frac{d\theta}{dt}+1{\cdot}9\omega^2\theta=0.\quad \text{Making } h_{\prime}^{2}=1{\cdot}9w^2-4k^2,$$

$$\theta=ae^{-2kt}\left\{\cos h_{\prime}t+\frac{2k}{h_{\prime}}\sin h_{\prime}t\right\}$$

$$\frac{d\theta}{dt}=-a\,.\,\frac{h_{\prime}^{2}+4k^2}{h_{\prime}}\,.\,e^{-2kt}\,.\,\sin h_{\prime}t.$$

$$\frac{d\theta}{dt}=0,\text{ when } t=0,\ t=\frac{\pi}{h_{\prime}}\ t=\frac{2\pi}{h_{\prime}},\text{ etc.}$$

Substituting these values of t in the preceding equation for θ, the amplitudes of vibration become successively

$$\alpha,\ \alpha l^{\frac{-2k}{h_{,}}\pi},\ \alpha e^{\frac{-4k}{h_{,}}\pi}\ \ldots\ldots$$

Similarly, the amplitudes of vibration of a straight vane are, successively,

$$\alpha,\ \alpha e^{\frac{-k}{h}.\pi},\ \alpha e^{\frac{-2k}{h}.\pi},\ \ldots\ldots$$

To determine the relative magnitude of the oscillation in these two cases, let us substitute for $\frac{2k}{h_{,}}$ and $\frac{k}{h}$ their original values,

$$\frac{2k}{h_{,}} = \frac{\mathrm{K}r}{\sqrt{1{\cdot}9\mathrm{K}-\mathrm{K}^2r^2}}$$

$$\frac{k}{h} = \frac{\mathrm{K}r}{\sqrt{4\mathrm{K}-\mathrm{K}^2r^2}}$$

If it be desired to take account of the diminution of pressure on the sheltered side of the straight vane, the value of K is not the same for both vanes, but will become so by multiplying K in the equations of the straight vane by the factor $1+n$. Making this correction, $\frac{k}{h} = \frac{\mathrm{K}r}{\sqrt{\frac{4}{1+n}\,.\,\mathrm{K}-\mathrm{K}^2r^2}}$. For all possible values of n, $\frac{2k}{h_{,}} > \frac{k}{h}$, and, consequently, at any time t, the amplitude of oscillation of the spread vane will be less than that of the straight vane, and so the former will sooner come to rest.

This difference in amplitude of oscillation is least when K^2r^2 is negligible in comparison with $1{\cdot}9\mathrm{K}$, in which case the difference between the amplitudes of oscillation is determined by the ratio $\sqrt{\frac{4}{1+n}} : \sqrt{1{\cdot}9}$ as exponential factors in the expression for the amplitude. This difference is increased by the term K^2r^2, r and K being constants depending on the length and surface of the vane.

The formulæ, therefore, show 1st, *that the oscillations of both vanes are smaller as the vanes are longer and larger ;* 2d, *that the spread vane is always more stable than the straight vane ;* and 3d, *that this advantage in stability is greater for long vanes than for short vanes, and is independent of the wind velocity.*

The above analysis obtains for a frictionless bearing. From the discussion of relative sensitiveness, we have found that with equal friction, a spread vane is more sensitive than a similar straight vane; consequently, for two vanes of equal sensitiveness, the spread vane will have the greater friction and will come to rest more quickly.

ART. VII.—*On the manner of Deposit of the Glacial Drift;* by O. P. HAY.

THE events of the "Great Ice Age," that period of the earth's history during which the deposits known as the "Drift" were scattered over a great portion of the Northern Hemisphere, have left many problems to perplex and to reward geologists, physicists, and astronomers. Some of these problems have already been solved; many yet await solution. That the principal agent concerned in performing this vast work was glacial ice; that its general direction of movement was from the north toward the south; and that it bore along with it, often from very distant localities, the materials of the Drift, are conclusions that are now pretty generally conceded. A problem whose solution has not yet been effected, is that relating to the manner in which the great glacial ice-sheet has deposited upon the older rocks its burden of materials that it had wrested from the strata and mountains farther north. There seems by no means to have been any dearth of theories on the subject, but none of them have been able to command general assent.

Prof. J. D. Dana has held the view that the materials of the drift were gathered up during the Glacial period, and for the most part deposited by the melting of the ice during the Champlain. His language is as follows:

"The earlier part of the Champlain period was the era of the melting of the great glacier and of most local glaciers . . . . and of the deposition of the sand and gravel of the glacier, except the relatively small part which had been earlier dropped," etc.—*Manual*, 1876, p. 542.

Prof. James Geikie appears to adopt the hypothesis that the Drift deposits accumulated under the glacier, but I am not aware that he has anywhere attempted to tell us how. His language in various passages seems to imply that these materials thus lying beneath the glacier were either constantly being pushed along or, at least, liable thus to be acted upon by

the moving ice. Dr. Archibald Geikie evidently holds similar views. He says:

"Underneath the great ice-sheet, and perhaps partly incorporated in the lower portions of the ice, there accumulated a mass of earthy, sandy, and stony matter (till, bowlder-clay, 'grund-moräne,' moraine-profonde, older diluvium') which, pushed along and ground up, was the material wherewith the characteristic flowing outlines and smoothed striated surfaces were produced."—*Textbook of Geology*, Ed. 1885, p. 894.

Again in a foot note on the same page, he says:

"It is difficult to explain by any known glacial operation, the accumulation of such deep masses of detritus below a sheet of moving land ice. Another problem is presented by the occasional and sometimes extensive preservation of undisturbed loose pre-glacial deposits under the till. The way in which the Forest-bed group has escaped for so wide a space under the Cromer cliffs with their proofs of enormous ice movement, is a remarkable example."

In our own country Profs. J. S. Newberry and N. H. Winchell have been most explicit in the enunciation of their views on this subject. Both are oppressed with the difficulties that lie in the way of understanding how the till can have accumulated under the moving glacier. The latter (Pop. Sci. Monthly, 1873; 293), puts forward the proposition that through the action of winds bearing dust and through the melting of the upper surface of the glacier, the materials now constituting the Drift accumulated on the surface of the ice sheet, and were either carried forward to the terminal edge and deposited there or, on the decay of the glacier, let down quietly on the rocky surface below. He has more recently re-affirmed these views (this Journal, 1881, 358), in calling attention to some of Capt. Dall's observations made on the coast of Alaska. There has been discovered in that region a sheet of ice of unknown extent and great thickness, that bears on its surface a thin soil, in which there is found growing in some places a rather luxuriant forest vegetation. In holes in this soil and in the underlying ice, there occur, besides decaying animal and vegetable matter, the bones of mammoths, buffaloes, etc.; and from these we may judge of the vast age of this stratum of ice. This is regarded by Prof. N. H. Winchell as being a "fossil glacier," the counterpart of which once spread over a considerable portion of our Northern States.

Prof. J. S. Newberry, in the volumes of the Geological Survey of Ohio, and elsewhere, insists strongly that the Drift materials could have accumulated neither on the surface of the great glacier, nor in any considerable thickness beneath it;

but that they were carried along in and under the glacier, and finally deposited as a terminal moraine, which, by the slow retreat of the glacier to the north, at length became a continuous sheet.

That wind, blowing for long ages over the glacier from the region lying to the south and west, may have deposited on it more or less dust; and that superficial melting may have brought some coarser materials to the surface, are suppositions that are entirely probable. The "shearing action" of the moving glacier may also, as H. Carville Lewis has recently shown us, have brought a certain amount of sand, gravel and bowlders from the lower portions of the glacier to the surface. But all these agencies combined probably did not result in producing any considerable superficial deposit. We cannot calculate on the dust with any confidence. Moreover, when once a thin covering of *debris*, from whatever source, had accumulated over the ice, it would protect this from further melting, and thus cut off one important source of addition. The intestinal motion of the glacier, too, would in all probability contribute little materials, on account of the sluggish movement of the glacial mass as a whole. As regards Capt. Dall's fossil ice-sheet, it cannot, in all probability, have any motion now, or have had any since the days of the mammoth; otherwise all those fossil bones would long ago have been shot out into the Arctic Ocean.

Against the theory that the bowlder-clay accumulated under the glacial sheet, Prof. Newberry makes protest on the ground that the underlying rocks show that the ice was in close contact with them, being separated from them by, at most, a thin stratum of sand and gravel. He says:

"It did not accumulate *beneath* the glacier, because the rock surface on which it rests, is planed down, grooved and carved, as it could only be when the ice fitted closely to it; and since two solid bodies cannot occupy the same space at the same time, the clay could only have accumulated in the places where it is found, after, or as, they were abandoned by the ice."—*Geol. Sur. Ohio*, vol. iii, 34."

Again (Geol. Sur. Ohio, vol. ii, 29):

"That the bowlder clay was not deposited *beneath* the glacier, as sometimes stated, is apparent from the fact that it covers the glaciated surface on which the ice rested, in a sheet sometimes a hundred feet in thickness. *It must, therefore, have accumulated at the margin of the glacier.*"

To these arguments it seems to me sufficient to reply that it is not necessary for us to suppose that, in order to produce all the observed effects on the underlying rocks, the ice-sheet continued to move over and in immediate contact with them dur-

ing *the whole Glacial period.* At the beginning of that period the ice with its enclosed bowlders and sand, did undoubtedly pass over the old surface and plane it down and groove it; but later there may have intervened between the glacial ice and this eroded surface a greater or less thickness of bowlder clay. Of course, some trouble may be experienced in comprehending how great glaciers thousands of feet in thickness and exerting a downward pressure of probably 50,000 pounds to the square foot* and containing sand, gravel and bowlders could move over deposits of bowlder clay, and instead of eroding them, continue to make additions to them.

This and many other difficulties have arisen from pushing too far the usually good practice of interpreting the events of the past by what we see occurring in our own day. At the present, we are acquainted with no glaciers except such as flow down steep inclines and terminate on such inclines either by melting or breaking off in the sea. On the other hand, the glaciers that deposited the Drift materials of the Western States after descending from the elevated regions of Canada, deployed out on nearly level plains for hundreds of miles. It is quite improbable that such a glacier would erode its bed and deposit its detritus in the same way that a Swiss glacier does. We could, perhaps, determine as correctly the eroding, transporting and depositing effects of running water by studying a roaring Alpine brook, as we can judge of the phenomena that attended the movements of the ancient ice-sheet by studying the Mer de Glace. But we know that the stream that in one part of its descent wears away the hardest rocks and bears along with it in its impetuous course, gravel and stones, may in its lower reaches, deposit the most impalpable sediments, and move so gently as not to disturb the most delicate leaf that may have fallen on its bed.

In like manner, as the glaciers of the Ice Age descended from the Laurentian Mountains and ploughed through the narrow channels now occupied by the Great Lakes, their eroding action was incessant and irresistible; but when those great streams of ice were spread out over Ohio, Indiana and Illinois, they became far less destructive. But even here, and however slow the motion, the underlying deposits were in most places worn away. But the soils and other deposits in depressed places of small area and behind cliffs of rocks probably would not suffer much erosion; since there the upper layers of the ice would flow on over the stationary lower layers. In this way we may account for the preservation of the soils and the contained remains of trees in the Cromer Forest-bed and for the abundant remains of trees and old soils below and even

* Newberry, Pop. Sci. Monthly, November, 1886.

in the Drift. In some cases such deposits may have been protected from glacial action by thick accumulations of compacted snow and ice which heralded the approach of the glacier.

While we may justly, I think, consider the eroding action of a glacier, like that of a running stream, to be some function of its velocity, the same cannot be said of the transporting and depositing powers of the glacier. When the velocity of the stream is reduced even a little, a portion of the materials it bears along may be deposited; but stones, large and small, once received into the bosom of the glacier are borne along, whatever may be the velocity. Yet we have evidences which show that in some cases bowlders have sunken in the glacial ice, so that they have, as Prof. J. D. Dana relates, got into a lower current running in a different direction. This is no more than we might expect of heavy rocks that are supported in a mass of ice which is constantly undergoing incipient liquefaction and regelation; and we may suppose that this tendency of rocks to gravitate downward would, in a slowly moving glacier, prevail over the tendency of the intestinal motion to throw them upward. However, it is not probable that these movements have had much to do with the making of the Drift deposits, to account for the enormous mass of which we must have recourse to other facts and principles.

What is known as the law of differential motion prevails in all glaciers. This law is a statement of the fact that different portions of the glacial stream move with very different velocities, the upper portions faster than the lower, the middle of the stream faster than the edges. The velocity of flow of the lower parts must be affected greatly by the character of the bed, and by the relative quantities of foreign materials enclosed.

There is another fact which must be considered at this point, namely, that there is in all glaciers more or less melting going on at the bottom. The sun's rays may cause the surface of the ice to thaw and waste away, but the heat that escapes from the earth must expend its energy in melting the bottom of the glacier. This action of the terrestrial heat is recognized by glacialists, and produces what is known as subsidence of the glacier. Accordingly we find streams of water escaping from beneath even the glaciers of the polar regions. The inevitable result of this melting of the lower layers of a slowly moving ice-stream must be to cause the rocks, sand and clay to accumulate in greater proportions in its lower parts. If we now connect this conclusion with the law of differential motion, we shall, I think, be able to account for the deposit known as the bowlder clay. While the great glacial ice-sheet of North America was descending from the Laurentian Highlands, where it took its origin, its weight was so enormous and its velocity

so great, that it powerfully denuded those regions and, bearing the *debris* along with it, constantly exposed a new surface to erosion. As it was urged on over the region of the present Great Lakes and was confined to comparatively narrow channels, it continued to gather up the wreck of the abraded strata below; but when it had debouched from these channels and had become spread out into a much broader sheet, its motion was much slower, and its pressure on the underlying strata much less than formerly. As it *was* in motion, however, it at first planed off the surface of all parts of the country that were not specially protected, and polished and scored the underlying rocks, as we find them to-day. But the earth's heat was constantly invading the lower layers of the glacier and melting it away. Thus it would happen that a larger and larger proportion of heavy materials would accumulate at the bottom of the ice-sheet. Stones would also doubtless often reach the bottom through crevasses, and streams of water from superficial melting would carry thither sand and clay.

It can scarcely be doubted that this accumulation of coarse, earthy, materials in the lower portions of the glacial mass would greatly retard the movement there; and with the increase of these materials, the retardation would go on until a time would come when all movement in those lower layers would cease, the small proportion of ice be melted out, and a permanent deposit formed. Other horizons higher up would then in their turn be similarly affected; and thus the bottom moraine might attain almost any thickness.

While contending that the great bulk of the Drift deposits were formed as above described, we may believe with Prof. Newberry and others that much of the glacial *debris* was carried forward and deposited in terminal moraines; and recently a number of these moraines have been described by Profs. Chamberlain and Wright, and others. We may again believe with Prof. J. D. Dana that large quantities of detritus were held in the body of the glacier and deposited on its final dissolution during the Champlain. Such a deposit, not having been subjected so long to the grinding action of the glacial mill, would naturally contain more and larger stones than the deeper parts of the Drift. Nor are we precluded from believing with Prof. N. H. Winchell that there may have been, here and there, tracts of soil visible on the face of the wide extended whiteness.

The conclusions reached above may be thus summed up:

1. A glacial ice-sheet moving over a nearly level surface would possess far less power of abrading its bed than the same glacier would have while descending a slope of high angle.

2. Through subsidence of the glacial mass, caused by the earth's heat, and through other influences, a constantly increas-

ing proportion of inert materials would collect in the lower layers of the moving ice.

3. The accumulation of such materials would tend to retard the motion of the lower portions of the glacier; and finally, when they formed a sufficiently great proportion of the mass, all motion of the lower portion would cease and a permanent deposit would begin and continue to be made.

4. Other masses of detritus might be deposited at the foot of the glacial ice-sheet as a terminal moraine, and still other masses on the top of the already formed deposit when the glacier finally melted.

ART. VIII.—*A New Photographic Spectroscope;* by C. C. HUTCHINS.

THE constant demands of spectrum analysis for ever increasing accuracy can be satisfied only by instruments of the highest dispersion and most perfect defining powers, and when applied to photography the dispersion must be produced directly, and not by enlarging lenses at the camera. The large apparatus of Rowland does this most beautifully, as the writer, who has used it for the past year, can testify; but the fact that a large room must be set aside for its accommodation, and moreover that the large concave gratings are very difficult to obtain, will forbid its use to most workers.

I have therefore devised the following simple, and it would seem upon short trial, effective arrangement for producing the desired results:

A rather long slit is placed at the focus of a crown glass (or better, quartz) lens of forty feet focus. The ray from the slit, after passing through the lens falls upon a large flat grating mounted to turn about an axis passing through the middle line of the ruled surface. The spectrum is projected by the same lens upon a horizontal arc of forty feet radius, and is observed a little to one side or above the slit. The spectrum will not be normal throughout its length unless the radius of projection be kept constant. I think this had better be provided for by employing two lenses of crown glass, the one nearer the grating fixed, the other movable, than by the use of a corrected lens, to avoid the absorption of flint glass in the achromatic combination.

More or less absorption when glass is used is unavoidable, and this, with the variation of the focal plane of the lens for light of different wave lengths, constitutes the most serious defects of the apparatus,—defects which are avoided in the

Rowland instrument. However, compensating advantages are not wanting. The Rowland apparatus integrates all impressions received at the slit. The ordinary comparison prism cannot be used with it, and the lower orders of spectra are too narrow to admit of convenient division at the camera; in fact, the spectra begin at nothing at the slit and spread in a widening band as we move toward the higher orders.

The new instrument possesses the advantages of the analyzing spectroscope. The spectrum can be made wide or narrow, or divided at the slit. A preliminary trial has given the following results:—A flat grating of 14,000 lines to the inch and a ruled surface $2\times1\frac{1}{2}$ inches was employed with a lens of 37 feet focus. The latter was placed close to the grating, and its spectrum observed near the slit. In the second spectrum b_1 and b_2 were fully an inch apart as projected on a screen, and D_1 and D_2 had a separation of 13 to 14 mm.

The excellence of the definition is shown by the fact that with an ordinary reading glass of six inch focus, E was seen double, and 14 lines were counted between D_1 and D_2. With this form of apparatus the amount of dispersion can be varied at pleasure by simply altering the relative distances of slit and camera from the grating, but in such a way that slit and camera shall occupy conjugate foci of the lens.

Jefferson Physical Laboratory, Harvard University, June 3, 1887.

ART. IX.—*A new Meteoric Iron and an Iron of doubtful nature;* by R. B. RIGGS.

The Abert Iron.

THIS meteorite was found entire and unlabeled in a collection of minerals made by the late Col. J. J. Abert, and presented to the National Museum by his son, Mr. J. T. Abert. It weighed originally 456 grams. Its specific gravity was found to be 7·89. Its cross section measured 50^{mm} by 37^{mm}. An analysis gave it the following composition:

Fe	92·04	Graphite	·03
Ni	7·00	C (combined)	·02
Co	·68		
P	·08		99·86
S	·01		

In composition, therefore, it is similar to the Nelson County meteorite. Nitric acid brought out characteristic Widmanstätten figures of the same octahedral marking with, though somewhat coarser than, those of the Grand Rapids meteorite. The fracture is distinctly octahedral.

An Iron of doubtful origin.

This iron was found on the farm of A. L. Hodge, three miles southwest of New Market Station, Jefferson County, Tennessee, in a region full of small iron furnaces, whence have come a number of pseudo-meteorites, among others the Hominy Creek, Rutherfordton and Campbell County irons. Special inquiries were therefore made by Professor Ira Sayles, who obtained it, as to the presence of furnaces in the vicinity. The immediate locality seemed to be free from them. The iron, full of cavities, is characterized by extreme hardness. Its weight was 640 grams, its specific gravity 7·61. Analysis determined its composition as follows:

Fe	88·27	P	1·80
Ni	·76	Si	·15
Co	·19	Graphite	·86
Cu	·03	C (combined)	1·46
As	tr.		
Mn	6·73		100·39
Mg	·14		

Treated with nitric acid, the polished surface developed quite fine markings not unlike Widmanstätten figures. The high percentage in manganese is possibly an objection to ascribing to it a meteoric origin. The presence of manganese, however, and in considerable quantities, is not so uncommon as many think. The Claiborne and Bitburg meteorites, both of unquestioned meteoric origin, contain respectively 3·24 per cent and 4·00 per cent.

Laboratory U. S. Geological Survey, Feb. 2, 1887.

ART. X.—*On an Aerolite from Rensselaer County, New York;* by S. C. H. BAILEY.

ABOUT the year 1863, Mr. H. Bancker, of Schaghticoke, N. Y., found, near the base of a large tree on the bank of the Tomhannock Creek in Rensselaer County, a stone of unusual appearance which he took home with him. After breaking off from it a fragment, the stone was laid aside and little further attention given to it until May, 1884, when it was sent to the writer who recognized it as an aerolite. The original weight was probably about $1\frac{1}{2}$ kilos, with an average diameter of about 10^{cm} and in outline was very round, not varying more than 2^{cm} in its extreme diameters. The crust was entire except where the fragment had been broken off, and a small crack or fissure, apparently caused by the blow from the hammer. The crust is of very uniform thickness, black, hard, thin, unglazed,

but quite smooth, with its line of union with the interior scarcely distinguishable, the clear black outside layer being but little thicker than stout note paper. The interior upon a freshly fractured surface is of a reddish brown color with a slight trace of blackish green when held in a certain light; its

texture is very fine, compact and hard, a little slaty in structure, and shows no traces of iron even under the lens, but when cut with the diamond saw, the iron appears in brilliant specks, very uniformly and abundantly distributed through the mass, so finely and equally disposed as to remind one forcibly of the fabric formerly known as "pepper and salt cloth." The stone bears a high polish which seems to give a degree of translucency to the surface which then assumes a mottled appearance, with patches of clear seal brown, spots of a gray color and a few "kugelchen" or grains of an oolitic structure. The aerolite was encircled with a zone of broad, deep pittings, as shown by the engraving. In its general aspect upon a cut surface it more nearly resembles the Seres, Macedonia, stone, than any with which I am familiar.

A circumstance, as connected with the enquiry, for how long a time an aerolite may resist the action of the soil and atmosphere, may here be mentioned. Mr. Bancker, its finder, states that many years prior to the discovery of this aerolite under the tree as before mentioned (probably fifteen years or more) he found this, or a similar stone in size and appearance, in his

swine yard. Its singularity attracted his attention and he carried it to his house and cleansed it, but in a little time it was forgotten or lost sight of. His definite recollection is that that stone was very like this aerolite in its general appearance, but he is wholly at a loss to trace any other connection of the specimen originally found by him and this aerolite found years afterwards on the clay bank of the creek at such a distance from his house. The fragment was broken from the stone after it had been found in 1863.

The exact data necessary to base correct conclusions upon, are wanting in this case, but the facts above stated may justify the supposition that stony meteorites may remain intact from the disintegrating effects of the soil and atmosphere for a much longer time than has heretofore been accorded them—assumed by one fully competent to form a trustworthy opinion (the late Professor C. U. Shepard) to be from a few months, to two or possibly three years.

The close, hard, semi-vitreous crust of the Tomhannock stone would suggest that so long as its exterior was not fractured by its fall, it might remain unharmed by atmospheric agencies alone for many years, or resist for a long time the action of the soil. For years this meteorite seems to have been exposed to one, or more probably, both, of these influences, yet when it came into my possession it showed no deterioration except from the blow from the hammer.

An analysis of the metallic portion of this stone by F. A. Wilber gave the following results:

Metallic iron	13·02
Nickel	3·06

the most notable feature being the excessive proportion of the nickel as compared with the iron. The composition of the stony portion has not yet been determined.

Cortlandt-on-Hudson, 23d Feb., 1887.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Boiling point of liquefied Ozone.*—From the fact established by Hautefeuille and Chappuis, that ozonized oxygen exposed under a pressure of 125 atmospheres to the temperature of boiling ethylene,—102·5°, yields liquefied ozone as a dark blue liquid which retains its state at this temperature for a short time even when the pressure is withdrawn, Olszewsky was led to the conclusion that the boiling point of ozone was probably but a little

below that of ethylene. Hence it should liquefy at the atmospheric pressure if the temperature was sufficiently low. At the temperature of $-150°$ no liquefaction occurred, no doubt because of the large amount of oxygen mixed with the ozone. But at $-181·4$, the temperature of boiling oxygen, the condensation readily took place and the dark blue liquid was produced. In very thin layers at this temperature it is transparent, but in layers 2^{mm} thick it is nearly opaque. On introducing the tube containing it into liquid ethylene at $-140°$, the ozone remained liquid, beginning to vaporize when the temperature of the ethylene had risen to near its boiling point. By means of a thermometer containing carbon disulphide, the temperature of the ethylene was fixed. At the moment of incipient ebullition of the ozone this thermometer indicated a temperature of $-109°$, corresponding on the hydrogen thermometer to $-106°$. Hence this value may be taken as the boiling point of liquid ozone. Sealed in a glass tube the liquid becomes a blue gas, which may be again condensed by placing it in boiling ethylene. Since a violent explosion ensues if the liquid ozone is allowed to come in contact with ethylene gas, great care is necessary to prevent this from taking place. Ethylene itself solidifies in boiling oxygen and fuses again at $-160°$.—*Wien Monatch. f. Chem.*, viii, 69; *Ber. Berl. Chem. Ges.*, xx, Ref. 245, May, 1887. G. F. B.

2. *On the Absorption-spectra of liquid Oxygen and of liquefied Air.*—Olszewsky has examined the absorption-spectrum of liquid oxygen, employing solar light for this purpose. Using a small direct-vision spectroscope, two strong dark lines were observed in the orange and yellow, which did not entirely disappear when the oxygen was all volatilized, and which were found to be present in the ordinary solar spectrum, faint at midday, but distinct at sunset. With greater dispersion, the oxygen lines expanded into bands resembling the telluric bands of the sun spectrum; remaining visible when electric or calcium light was substituted for sunlight. On increasing the layer of liquid oxygen from 7^{mm} in thickness to 12^{mm}, two more bands appeared; a faint one in the green and a stronger one in the blue. The wavelengths of these four bands, measured from the central line, were 628, 577, 535 and 480 millionths of a millimeter. The first of these bands is distinguished by its breadth, the second by its intensity; the last two bands, which are more feeble, do not appear in the sun spectrum. The air, whose spectrum was examined, was carefully freed from moisture and carbon dioxide before liquefaction. No new bands appeared, the spectrum consisting mainly of the bands 628 and 577, above mentioned, which were faint. They became stronger as the liquid became richer in oxygen by the evaporation of the nitrogen mixed with it. Of the four telluric bands in the sun spectrum A, B, α and δ, which Ångström has shown cannot well be due to aqueous vapor on account of their stability, the two latter coincide with the two strongest of the above oxygen bands. Egoroff concluded from

his examination of the spectrum of compressed oxygen gas that A, B, and probably α, are due to oxygen. To these Janssen added some other bands, seen by him in the spectrum of compressed oxygen. As to the lines A and B, Olszewsky has not been able to make sufficiently exact observations in that part of the spectrum of liquid oxygen in which they occur, to enable him to establish definitely their existence in that spectrum.—*Wien Monatsch. f. Chem.*, viii, 73, *Nature*, xxxvi, 42, May, 1887.

G. F. B.

3. *On the action of Platinum on a mixture of Oxygen and Ammonia gases.*—KRAUT has modified the form of apparatus which he at first devised to show the action of oxygen upon ammonia in presence of platinum. He now takes a strip of platinum or palladium foil 5 or 6^{cm} long, 1^{cm} broad and $0{\cdot}2^{mm}$ thick, and hangs it in a flask of 800 or 900^{cc} capacity by means of a platinum wire. Through the stopper of the flask two glass tubes pass each about 4^{mm} in diameter and bent at right angles. One of these tubes terminates just below the stopper, the other two-thirds the way down. The flask is now filled to one-quarter or one-third its volume with a 20 per cent solution of ammonia, the ignited foil is hung within it, of course so as not to touch the liquid, and a rapid current of oxygen is admitted through the longer tube. On shutting off the gas, the foil rises to a dark red heat and white clouds of ammonium nitrate are formed. If the oxygen be admitted for a second time for a few seconds, the foil glows still brighter and brighter, and yellow vapors of nitrogen tetroxide appear. By a third or fourth admission of oxygen the color of the gas in the flask may be made dark enough to be visible at a distance, and this without danger of explosion and without igniting the oxygen.—*Ber. Berl. Chem. Ges.*, xx, 113, April, 1887.

G. F. B.

4. *On two new Hydrates of Potassium hydroxide.*—The only definite hydrate of potassium hydroxide thus far known has the formula $KOH.(H_2O)_2$ and crystallizes from a hot concentrated, aqueous solution in rhombic octahedrons. GOTTIG has now described two more hydrates, obtained not from aqueous but from alcoholic solutions. To produce the first of these, pulverized potassium hydroxide is rubbed in a mortar with 96·8 per cent alcohol so as to obtain a solution of sp. gr. 1·050 to 1·058, and the mass is filtered. Even during filtration, large prismatic crystals separate, and on cooling, the filtrate becomes a mass of such crystals. On analysis these crystals gave the formula $(KOH)_2(H_2O)_9$. They fuse below 40°, and give up 41·5 per cent (about 3 molecules) of their crystal water on standing 144 hours over sulphuric acid. The second hydrate is obtained from solutions of potassium hydroxide in 96·8 per cent alcohol, but which have a specific gravity of only 0·980 to 0·985. Such a solution is boiled down to one-half its bulk, the boiling point rising from 95° to 116°. On cooling, exceedingly long, delicate needles separate, and at 35° the mass is nearly solid. During drying these needle

crystals have a characteristic behavior. They split into fine filaments, so that the mass in an approximately dry state resembles cotton wool. On complete drying these crystals unite without any change of composition to form a hard compact mass. Analysis gave for the composition of this hydrate the formula $(KOH)_2(H_2O)_5$. It begins to fuse at 50°, and loses over sulphuric acid 25·7 per cent water, reducing itself to KOH, H_2O. A fragment on water shows active rotation.—*Ber. Berl. Chem. Ges.*, xx, 1094, April, 1887. G. F. B.

5. *On the Sugar yielded by Hesperidin and Naringin.*—WILL has compared together the products yielded by the glucosides hesperidin and naringin, when they are boiled with dilute sulphuric acid. After thus treating hesperidin, the hesperidin and the sulphuric acid were removed and the solution evaporated to a syrup. This was extracted with alcohol and fractionally precipitated with ether. From the later fractions, dissolved in alcohol, fine clear brilliant crystals separated on evaporation which were identified as isodulcite. They fused at 94°, rotated to the right and were not fermentable. The mother liquors, however, contained still another sugar, and this a fermentable one. Treating the syrup with phenyl-hydrogen hydrochlorate and sodium acetate, a mixture of the isodulcite compound and the dextrose compound phenylglucosazone, separated in yellow needles. The two were easily separated by treatment with acetone in which the latter is insoluble. Naringin treated in the same way gave also isodulcite and dextrose.—*Ber. Berl. Chem. Ges.*, xx, 1186, April, 1887. G. F. B.

6. *On the Thermo-chemistry of Antimonous sulphide.*—In a memoir on the thermo-chemistry of antimonous sulphide, BERTHELOT has studied (1) the thermic formation of orange antimonous sulphide; (2) the thermic formation of the chlorosulphide, together with secondary products such as hydrogen sulphantimonite and other sulphantimonites and hydrogen-antimonous chloride; (3) the thermic formation of the two antimonous sulphides, the one black, crystalline, anhydrous, the other orange, amorphous, hydrated; and (4) the reciprocal actions between hydrogen chloride, hydrogen sulphide and antimony salts, viewed in the light of the earlier results. The following are his conclusions: 1st. Inverse actions are produced in cases where the sign of the heat evolved in the reaction of the two bodies, such for example as antimonous sulphide and hydrogen chloride, is changed by the combination of one of them, either with a third body, such as water, to form hydrates, or even with one of the products of the reaction itself. 2d. The chemical action is not reversed suddenly, but along a certain gradation of intermediate compounds, such as hydrates, sulph-hydrates, chlorhydrates, oxychlorides, chlorosulphides, etc.; compounds the proper heat of formation of which is included in the phenomena and tends to complete the thermic interval of the principal reactions. 3d. These secondary compounds for the most part exist only in a state of partial dissocia-

tion; that is to say, a state of tension of their components. 4th. There are compounds which determine and which regulate the chemical equilibrium between antagonistic bodies, according to the conditions of their own existence and of their dissociation; it is at this point that the physico-chemical laws of dissociation intervene, laws which are the objects of study at present by so many savants. A fundamental distinction is thus established between those reactions which are due to the internal energy of systems, energy the gradual dissipation of which is conformable to the principle of maximum work, and those opposite effects which are due to foreign energy, such for example as calorific energy which acts generally to produce changes of state and dissociation. The whole of the mechanics of chemistry is explained by the coaction of the laws which preside over these two orders of phenomena.—*Ann. Chim. Phys.*, vi, x, 123, January, 1887.

G. F. B.

7. *On a new Color reaction for Bismuth.*—HASELBROEK has studied the action of hydrogen peroxide upon bismuth salts and finds that if a weak solution of the peroxide made alkaline with potassium or sodium hydrate, be added to bismuth subnitrate in a test tube, the white subnitrate on heating becomes brownish yellow, the mixture at the same time evolving oxygen. The bright orange-yellow powder thus obtained is amorphous, becomes brown on heating, and dissolves in mineral acids with evolution of gas, oxygen when sulphuric acid is used, chlorine when hydrochloric acid is employed. Analysis showed it to be bismuth pentoxide, Bi_2O_5, already observed by Arppe, and capable of forming bismuthic acid. The formation of this body is a delicate test for bismuth. If bismuth hydrate is precipitated in presence of hydrogen peroxide and excess of alkali or ammonia, the slightest trace shows a yellow color. If a drop of a 3 per cent peroxide solution be diluted with 150^{cc} water, made strongly alkaline, and a few drops of a dilute solution of bismuth nitrate be added the yellow precipitate appears on warming. One part of H_2O_2 in 100,000 of water may thus be detected. It also constitutes an extremely delicate test for bismuth.—*Ber. Berl. Chem. Ges.*, xx, 213, Feb., 1887.

G. F. B.

8. *A new Heat Measurer.*—Mr. C. Vernon Boys exhibited an instrument which he terms the Radiomicrometer to the Royal Society, March 24. The instrument is a modification of one invented by M. D'Arsonval, and consists of a minute thermal junction forming one side of a parallelogram of which the other three sides are of copper. This thermo-electric circuit is suspended between the poles of a magnet. It is evident that when radiant heat falls upon the thermo-electric junction forming one side of the parallelogram an electrical current is formed which turns in the magnetic field, where it is placed so as to include the greatest number of lines of force. The parallelogram made by Mr. Boys embraced one square centimeter. The thermo-electric junction consisted of a bar of antimony and of bismuth, each piece being

$5 \times 5 \times \frac{1}{6}$mm., soldered edge to edge. The circuit was supported by a torsion fiber and provided with a little mirror. With a magnetic field of only 100 units the instrument showed the heat which would be cast on a half penny by a candle flame at a distance of 1168 feet. With a stronger magnetic field the instrument is capable of much greater sensitiveness. The author calculates that an instrument can be made which would show a change of temperature at the junction of $\frac{1}{1000000000}$ of a degree of heat. Mr. Boys also showed a motor which consisted of a cross, the center being antimony and the arms bismuth; to the ends of the arms are soldered four copper wires, the three ends of which are joined by a ring of copper. When the spark from a blown out match is held near this arrangement it rotates rapidly. If the spark is held on the right hand side of the north pole the motor revolves indifferently in either direction. If the spark is held on the left hand side the motor stops. "We have, therefore, an electric magnetic motor which goes having neither sliding nor liquid contacts."—*Nature*, April 7, 1887. J. T.

9. *Color mixtures.*—At a meeting of the Physical Society in Berlin, March 4, Professor Vogel exhibited an experiment which can serve to dispel the popular notion that blue and yellow light when mixed necessarily produce green. Three fluids were employed in three flat phials. Phial No. 1 contained acid yellow (Säuregelb); phial 2, solution of ammoniacal copper; phial 3, aniline blue. 1 and 2 superimposed on each other gave green; 1 and 3 a fiery red.—*Nature*, April 7, 1887. J. T.

10. *Dispersion of rock salt.*—H. E. Ketteler discusses the recent results of Professor Langley, applying a formula for dispersion which he has lately published, Wied. Ann., xxx, p. 299, 1887. He arrives at the following conclusion: "The member, $-K\lambda^2$ of the dispersion formula, expresses the absorption of radiant heat, and all dispersion theories which do not take this into account are untenable."—*Ann. der Physik and Chemie*, No. 6, 1887, p. 322. J. T.

11. *Effect of pressure on thermometer bulbs.*—Professor Spencer Umfreville Pickering calls attention to errors which can arise from a difference of pressure upon thin thermometer bulbs. When the coefficient of expansion of the bulb is large, irregularities sufficient to cause considerable errors may arise. The bulb subjected to pressure apparently behaves like thin tin vessels where a small addition or removal of pressure will cause a considerable alteration in the form of the vessel. Glass cylinder bulbs were found to be more rigid than spherical ones.—*Phil. Mag.*, May, 1887, p. 406. J. T.

12. *On an objection to Professor Morley's Attempt to explain the less amount of Oxygen in the Air observed by him in the region of an Anti-cyclone;* by MAX SCHUMANN (from the "Meteorologische Zeitschrift," Bd. 4, June, 1884, translated by the author.)—Mr. E. W. Morley explains in this Journal, III, vol. xxii, p. 471, 1881, the result found by his experiments (contrary

to the conclusion of M. Folly*), that a less amount of oxygen in the atmosphere always coincides with a barometrical maximum, through the descending current which, in anti-cyclones, brings downward air deficient in oxygen from higher elevations. The proposed explanation is not satisfactory, because the descending air in the region of an anti-cyclone does not proceed from those elevations in which a less amount of oxygen may be expected. There is a certain altitude indeed—and this is certainly greater than that at which those atmospheric processes take place, the combined effect of which is called "weather"—up to which the amount of oxygen may be regarded as invariable. The air, found by Mr. Morley to contain less oxygen, proceeds from elevations inferior to those, because that air is not sucked down from strata above that limit, but only takes a circular path induced in a region of disturbed air by the ascending current. In consequence of this circular path, which is easily understood by thinking of a ring on a horizontal plain in the center of which the air ascends and is sucked over the upper edge of the ring down along the outer surface and under the lower edge back to the center of the ring, the air descending on a region of high barometrical pressure proceeds at all events only from those elevations in which the amount of oxygen may be regarded as invariable.

Heidelberg, March, 1887.

II. Geology and Mineralogy.

1. "*On a Seismic Survey made in Tokio in* 1884–85." Read by Professor John Milne, before the Seismological Society of Japan, on January 27, 1886.—This paper makes a pamphlet of 36 pages with maps and diagrams, and appears to be from the unpublished tenth volume of the Transactions of the Society; although that is not stated upon it. It is a fuller account of experiments briefly described in his "Fifth Report" to the British Association at the meeting in 1885, and noticed in Nature (xxxii, 526) at that time. A number of similar seismographs were installed at different points in the grounds of the Imperial College of Engineering, one being at the bottom of a pit ten feet deep and another in a house supported on cast iron shot. The instruments were connected and simultaneously put in operation by electricity. During the year of observation, March, 1884, to March, 1885, fifty earthquakes occurred whose automatic records were studied. A map of the grounds is given and copies of some of the record diagrams. In general the results differed very sensibly at the various stations, the motion being usually greatest on the low grounds. The greatest amplitude marked at any station was $2{\cdot}5^{mm}$, while the same earthquake at another station gave only $0{\cdot}05^{mm}$. The greatest maximum velocity recorded is 19^{mm} per second. The greatest acceleration recorded was 300^{mm} or about one foot per second. In the house resting on shot the least

* In an essay of Mr. Morley in this Journal, III, vol. xxii, p. 429, 1881.

motion was found when the shot used were small, about a quarter of an inch in diameter. The observations in the pit apparently indicate that an earthquake's motion at a distance from its origin is practically superficial and that a building whose foundations rose freely from hard ground at the bottom of a trench, ought to feel but little movement; but these inferences need to be tested by further experiment.

The writer has also received a little 16mo. pamphlet of twenty-three pages "On the causes of Earthquakes," which is a reprint from the columns of the Japan Mail of the shorthand report of a popular lecture delivered in Tokio by Professor Milne on October 16, 1886. In the reprint the original columns of the newspaper have been curiously transposed, so that to get the lecture in proper order the pages of the pamphlet must be taken thus: 1–7, 14–20, 7–14, 20–23. The exact line of separation on pages 7, 14 and 20, will be evident to the reader. C. G. R., JR.

2. *On Submarine Valleys on the Pacific Coast of the United States;* by GEORGE DAVIDSON. (Bulletin California Acad. Sci., ii, 265, January, 1887.) Off the Pacific Coast south of Cape Mendocino, the distance to the 100-fathom line is generally about ten miles; there is then a sharp descent to 500 or 600 fathoms, and from this a decline to 2000 to 2400 fathoms within 40 or 50 miles. Within the marginal plateau bounded by the 100-fathom curve, the soundings of the coast survey have found several deep valleys. Mr. Davidson reported to the California Academy, in a former paper, the existence of one of those remarkable valleys in Monterey Bay, leading toward the lowlands at the great bend of the Salinas River; another off Point Huaneme at the eastern entrance to the Santa Barbara Channel, heading toward the opening of the Santa Clara valley; one or two at the mouth of the Laguna Mugu; two or three off the southern point of Carmel Bay, the deepest of which goes far into the bay.

As more recent discoveries, he mentions three valleys off the coast south of Cape Mendocino. One is off Point Delgada at Shelter Cone; it cuts through the marginal plateau in a direction toward the culminating point in the mountains of the coast, a peak 4236 feet high. The 100-fathom line is six miles off Point Delgada; but in its course where crossed by the valley the depth reaches 400 fathoms; and a depth of 100 fathoms is within one and a quarter miles of the shore, while 25 fathoms is near the shore cliffs.

A few miles farther north a second submarine valley comes in from the west-southwest, reaching toward the coast three miles north of Point of Gorda and less than a mile north of the mouth of the Mattole River. At the head of this steep-sided valley there is a depth of 30 fathoms one-third of a mile from the shore, and of 100 fathoms one-third of a mile outside of this; and at the edge of the 100-fathom plateau, here six miles from Point Gorda, the depth is 520 fathoms. It is remarkable that the barrier of coast-line at the head of this valley is over 2000 feet high.

A third submarine valley exists between Point Gorda and Cape Mendocino; five miles southwest of the Cape. The depth of 450 fathoms occurs $6\frac{1}{2}$ miles S.W. by S. of the cape, and 100 fathoms at the usual position of the 25-fathom line.

The valleys take in the cold water that come down the coast, outside of the inshore northward-flowing eddy current, and a cold water fauna. They are places where vessels may misjudge as to their position from failing to find bottom at the usual depth; and one steamer was thus lost.

3. *Triassic Mammals, Dromatherium and Microconodon.*—Prof. H. F. Osborn has a paper, in the Proceedings of the Academy of Natural Sciences of Philadelphia for 1886, p. 359, giving the results of a study of the two existing specimens of jaws of upper Triassic Mammals from the Chatham coal-fields of North Carolina, one of them in the collection of Williams College, and the other at the Philadelphia Academy. He shows that the figures published by Prof. Emmons are not correct and apparently because made from the two specimens which were wrongly referred to one genus by Emmons. He gives a new figure of the jaw of *Dromatherium sylvestre*, with a description, and names the other species *Microconodon tenuirostris*, which he also figures and describes.

4. *Artesian well at St. Augustine, Florida.*—A brief report on this artesian well by Mr. Kennish, states that the boring, below 50 feet of sand and shells, passed through about 45 feet of coquina or shell-rock, and indurated clay and sand; 7·5 of blue clay affording sulphurous water; fossiliferous limestone affording corals, shells, etc., to 600 feet below the surface, affording 3,000,000 gallons of pure water free from sulphur at 400 to 450 feet below the surface, 7,000,000 per day, at 500 to 550. Below 770 feet to 1120 feet, hard limestone, with increase in the amount of water; below, to 1225, sandstone with flint; below 1290 in fossiliferous limestone to 1400 feet. The supply of water obtained is stated to be 8,000,000 gallons per day, which is twenty-eight times that from the longest well at Charleston, S. C.; and the power secured, 75 horse power. The increase of temperature downward was about one degree Fahrenheit in every 50 feet of depth, the temperature at bottom being 86° F.; but what care was used in obtaining the temperature is not stated. The well was bored for the Ponce de Leon Hotel, under the charge of Mr. H. M. Flagler.

5. *Formation of the cone in the Halema'uma'u basin.*—On page 239 of the last volume, a view is given of the cone in the Halema'uma'u basin, Kilauea, and a letter received from Mr. Frank E. Dodge, of the Hawaiian Government Survey, dated January 14, 1887, is cited from. The same letter says further with reference to the formation of the cone: "I think it first appeared as a ridge extending east and west in the northern half of the pit, and other portions appeared successively until the whole circuit was completed—all *rising slowly as though floating on the surface of the new lava lake.* The central depression (of the cone) occupies

the site of the deep centre of the basin shown on Mr. Emerson's map, 900 feet deep." J. D. D.

6. *Report on the Geology of New Jersey for* 1886, by the State Geologist, Prof. G. H. Cook. 254 pp. 8vo.—In the report of Dr. Britton on the Archæan belt it is stated that no division of Huronian has yet been identified. The kinds of rocks are mentioned and these do not include labradoritic kinds, or prominently, pyroxenic kinds. The iron ore beds are all of magnetite, no hematite occurring in the Archæan except as a surface alteration production derived from the magnetite. The iron-bearing strata belong with the older part of the Archæan, differing thus apparently from those of the Lake Superior region. Much valuable information is given on the stratification of the rocks, and on their kinds and relations. The statement is made (on p. 70) that the term Huronian was introduced by Dr. T. Sterry Hunt in 1855. But in his geological address of 1871, Dr. Hunt says: "The crystalline infra-Silurian strata to which the name of the Huronian series has been given by the Geological Survey of Canada," words he would not have used, had he himself been the giver. The term first appears in print in the "Esquisse Géologique du Canada;" which was prepared for "L'Exposition Universelle" at Paris of 1855, and was printed in Paris in 1855. But the title page has the names of both W. E. Logan and T. Sterry Hunt; and the preface expressly states that "for the geological facts and what relates to the physical structure of the country, all is due to Mr. Logan ("tout est dû à M. Logan"); the mineralogy and also the chemistry of the metamorphic rocks and the mineral waters, are the labors of M. Sterry Hunt, by whom the sketch was drawn up."

The report also treats of the Triassic; the drift; mining of iron and zinc ores; the greensand beds which are Cretaceous except the upper marl-bed, and gives new analyses of the marls. It is remarked that the greensand marls have their chief value in the phosphoric acid (as calcium phosphate) present; that those containing calcium carbonate are most durable; that the potash has but little present value, since it exists in a silicate and is hence insoluble; that the marls containing little of either phosphoric acid or calcium carbonate, become active fertilizers when composted with quick lime.

7. *Bulletin of the Scientific Laboratory of Denison University*, Granville, Ohio, vol. ii, parts 1 and 2, May, 1887. Edited by C. L. Herrick, Dept. Geol. and Nat. Hist., and A. D. Cole, Dept. Chem. and Phys.—The Scientific Department of Denison University is among the more active of the country, and especially through the ability and energy of Prof. Herrick, who is artist and engraver as well as investigator. The Bulletin, recently issued, commences with an account of the Geology of Licking Co., Ohio, with seven crowded plates of figures of fossils, a few of which are of new species, and appended to it is a paper on the Bryozoa of Flint Ridge with one plate, by A. F. Foerste. There are also parts 2 and 3 of a paper on the Clinton Group of

Ohio, with three plates, by Mr. FOERSTE; on the Geology and Lithology of Michipicoten Bay, by C. L. HERRICK, W. G. TIGHT, and H. L. JONES; on the determination of the Horizontal Component of the Earth's Magnetic force, by L. E. AKINS, explaining method of observation; and a list of Algæ of the vicinity of Granville, by H. L. JONES.

The paper on the Geology and Lithology of Michipicoten Bay bears on the Huronian question and is illustrated by three plates. The rocks are granite, which is described as eruptive; the metamorphic schists, mica schist, chlorite schist, hornblende schist, epidote schist, gneiss, etc., with dioryte and diabase; and unconformably over the schists there are the conglomerates and sandstones with intercalated and intrusive diabase of the Kewenaw series, which, besides covering Michipicoten Island, occur on the shore at Cape Cargantia. The conglomerates consist of material derived from the schists and other crystalline rocks. It is inferred that a long interval elapsed between the era of the latter formation and that of the schist.

8. *A sketch of the Geological Development of the Pacific Slope;* by G. F. BECKER.—This short but interesting paper is No. 5 of the Proceedings of the Natural History Society of Newport, R. I.

9. *First Report on the Florida State Geological Survey,* 1887: by J. KOST, M.D., LL.D., 32 pp. 8vo, 1887. This first report contains no results of new investigations.

10. *Brief notices of some recently described minerals.*—LANGBANITE. Occurs in hexagonal crystals, varying in habit from short prismatic to tabular; the latter are quite complex and resembles apatite somewhat, but differ from it in being holohedral; the vertical axis is 1·6437. The other physical characters are: hardness =6·5, specific gravity =4·918; luster metallic; color iron-black; streak brown; fracture conchoidal. An analysis yielded:

Sb_2O_5	SiO_2	MnO	FeO
15·42	10·88	64·00	10·32=100·62

This the author interprets as a silicate of manganese (Mn_5SiO_7) with antimonate of iron ($Fe_3Sb_2O_8$) in the ratio 37:10. Långbanite occurs sparingly in granular limestone with schefferite, magnetite and rhodonite at Långban in Sweden. Described by G. Flink in *Zeitschr. Kryst.*, xiii, 1, 1887.

WEBSKYITE. A decomposition-product of serpentine occurring in crevices in the paleopikrite of Amelose, near Biedenkopf, in Nassau. It has a black color in the mass, but green or greenish brown in thin splinters; specific gravity 1·771. The mean of two analyses gave:

SiO_2	Al_2O_3, Fe_2O_3	FeO	MgO	H_2O	H_2O (below 110°)
34·91	9·60	3·13	21·62	9·84	21·20=100·30

Named after the late Professor Websky, of Berlin, by R. Brauns, *Jahrb. Min.*, *Beilageband* v, 318, 1887.

PSEUDOBIOTITE. Knop closes an interesting article on the composition of biotite, in which he gives analyses of varieties from several localities, by describing an altered kind under the name of pseudobiotite. It occurs in scales in the crystallized limestone of the Kaiserstuhl. The mean of two analyses gave :

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3 ?	MgO	K_2O	H_2O
35·91	1·15	15·18	10·85	0·89	22·80	2·90	10·77=100·45

The author does not regard it as a definite compound.—*Zeitschr. Kryst.*, xii, 607, 1887.

GRIQUALANDITE. Described by G. Grant Hepburn as a hydrous ferric silicate pseudomorphous after crocidolite from Griqualand West, South Africa. The supposed new mineral, however, was obviously the siliceous material extensively used as an ornamental stone (tiger-eye) which consists of silica more or less impregnated with the yellow iron oxide derived from the alteration of the original crocidolite.—*Chem. News*, May 27, 1887.

MANGANOTANTALITE.—A member of the tantalite-columbite group of minerals described by Arzruni from the Uralian gold washings. It is known from a single crystal only, which has in general the habit and dimensions of ordinary columbite. The specific gravity was found to be 7·37, and the color, nearly black by reflected light, was brown to orange-red by reflected light in thin splinters. An analysis by Blomstrand gave :—

Ta_2O_5	Nb_2O_5	SnO_2, WO_3	FeO	MnO	CaO	ign.
79·81	4·47	0·67	1·17	13·88	0·17	(0·167)=100·33

This corresponds to the formula $11MnTa_2O_6 + FeNb_2O_6$. The mineral is related therefore to the manganese tantalo-niobate from Branchville, G.=6·59, analyzed by Comstock (this Journal, xix, 131, 1880), and to the mangantantalite, G.=6·3, of Nordenskjöld (3d Appendix to Dana's Mineralogy, p. 118). It contains, however, much more tantalum and correspondingly has a higher specific gravity than either of these minerals.—*Verh. Russ. Min. Ges.*, 1886.

CRISTOBALITE.—This name has been given by vom Rath to some small octahedral crystals found at the tridymite locality of Cerro San Cristobal, near Pachuca, Mexico. They are in part spinel-like twins, and occur intimately associated with the tridymite, in cavities in the andesite. An analysis showed them to consist essentially of silica, and the author is uncertain whether to regard them as a new form of crystallized silica or as pseudomorphs after some undetermined mineral, but inclines to the latter opinion. An examination by Bauer showed them to possess a rather strong abnormal double refraction. In this respect they are like the unexplained cubic crystals of silica found by Lasaulx on the sulphur of Girgenti and called melanophlogite.

11. *Uraninite and monazite from Canada;* by G. C. HOFFMANN. (Communicated).—These minerals were found at the Villeneuve mica veins, situated in the township of Villeneuve, Ottawa county, Quebec. The workings are on what has been described as a

coarse pegmatite vein, composed of quartz, orthoclase or microcline, albite, and muscovite, with occasionally garnet and black tourmaline. Some of the crystals of mica, which is of excellent quality, are of very large dimensions; the albite exhibits a beautiful play of color and some of the crystals of tourmaline, without being of a great diameter, are of remarkable length. A nodular fragment of uraninite was found, weighing about one pound. The specific gravity was 9·055. The specimen, to which was attached a little muscovite, had on one portion of its surface a moderately thick incrustation, the prevailing color of which was yellowish red to scarlet red, a small portion of the same had, however, a pure sulphur-yellow color; this material, which is most probably gummite, had a specific gravity of 3·78.

The specimen of monazite was in the form of a rounded mass, to which was attached a little muscovite and feldspar; it weighed not less than twelve and a quarter pounds; structure compact, without any indication of crystalline form; color, reddish brown; lustre, resinous; specific gravity, 5·138. Its blowpipe characters and general composition are those of monazite. The junior assistant, under my supervision, made a quantitative analysis, the results of which are only approximate; he found it to contain phosphoric anhydride 26·95, oxides of metals of the cerium group (precipitated as oxalates) 64·45 per cent; also silica 5·85 per cent. The loss on ignition was 1·39 per cent; water, direct estimation 0·91 per cent.

III. Botany and Zoology.

1. *Die natürlichen Pflanzenfamilien nebst ihren Gattungen und wichtigeren Arten, insbesondere den Nutzpflanzen bearbeitet, unter Mitwirkung zahlreicher hervorragender Fachgelehrten, von* A. Engel und K. Prantl.—The scope of this work renders it one of the most welcome recent contributions to botanical literature. The aim of the projectors is to furnish a comprehensive handbook of systematic botany, supplementing the Genera Plantarum. Such a work is adapted to the wants of special students, and also meets the needs of pharmacists, physicians, foresters and teachers. It is furthermore designed to answer the questions which are constantly coming up in general reading, and can be widely used as a book of reference.

It is to consist of about 100 numbers, each having 48 octavo pages, to be illustrated by several thousand figures on wood. The editors are well known for their good judgment and discrimination: the list of contributors contains the names of a large number of specialists. The name of the lamented Eichler appears in this list; from a fragment of his study of Coniferæ, given in the prospectus, it would seem that this important part might have been finished by him before his fatal illness had pronounced itself.

The first installment comprises a part of the true Palms. This has been done by Professor Drude. The text gives a full presen-

tation of the systematic relations of the groups, a full account of the structure, a connected sketch of the life history of palms, starting from germination. The topics of distribution and uses are treated in a reasonably full manner, and all has been done in a careful and attractive way.

The illustrations are of the first order, comparing well in every way with any yet published in any country. The low price of the great work (1.50 marks, for each number of forty-eight pages), should place it in the libraries of most of our Colleges. The parts are to appear about every month, and the whole work will be finished in six years. G. L. G.

2. *An introduction to the Study of Lichens;* by HENRY WILLEY, New Bedford.—We have been long in need of some English work which should give in a condensed and easily comprehensible form the main facts concerning the structure of lichens and their classification, since most recent text-books treat lichens from a developmental point of view and do not give what may be called the common-place facts which every beginner wishes to know. The present work of 43 pages besides a supplement and 10 plates, is especially adapted to the needs of those who wish something to enable them to use understandingly the synopsis of Prof. Tuckerman. There are chapters on the structure of lichens and the method of collecting which give the essentials in a compact and convenient form, as well as one on the distribution of North American lichens and an excellent summary of the progress of lichenology. The most valuable part of the work for lichenologists is the supplement which gives an enumeration of North American species of the genera not included in Tuckerman's Synopsis, as far as published, from *Bœonrycei* to *Verrucariei.* This is in fact a revised edition of the latter part of Willey's List of North American Lichens published in 1873, with an enumeration of all species discovered since that date and descriptions of 11 new species, 2 of them by Tuckerman. It is of interest to note that the number of species of the orders above named now known in North America is greater by more than a half than in 1873. The plates represent the spores of North American genera.

W. G. F.

3. *The West Indian Seal* (*Monachus tropicalis*).—The Bulletin of the American Museum of Natural History, vol. ii, No. 1, contains a description of the West Indian seal. Up to December, 1886, only one specimen was known to be in any Museum, the National Museum at Washington, a specimen formerly in the British Museum "having disappeared." In December, Mr. H. L. Ward, of Rochester, son of Prof. H. A. Ward, the energetic head of the establishment for supplying Museums, visited "The Triangles" off the coast of Yucatan, with Mr. Fernando Ferrari-Perez, of Mexico, found the seals numerous and obtained a large number of skins and some skeletons, which were brought to Rochester. Those of the skins representing the male, female and young, and one skeleton, are now in the American Museum, New

York. These specimens and the others in Rochester have afforded Prof. Allen material for his paper, which is illustrated by four plates. The same number of the Bulletin contains a paper by Prof. Allen on Squalodont Remains from Charleston, S. C., with two plates.

4. *Selected Morphological Monographs*, by members of the Johns Hopkins University; Edited by W. K. Brooks, Ph.D., Director of the Chesapeake Zoological Laboratory.—This volume, in 4to., contains four papers, of high merit, which have already appeared elsewhere; W. K. Brooks on Lucifer, a study in morphology, with 11 plates; on the Life History of the Hydro-Medusæ, a discussion of the origin of the Medusæ and the significance of Metagenesis, with 8 plates; and on the Stomatopoda, with 16 plates; and by E. B. Wilson, on the development of Renilla, with 16 plates. Only 100 copies published. Price, $7.50 each, postage or express charges included.

No. 8, vol. iii, of the Studies from the Biological Laboratory of the University contains a contribution to the Embryology of the Prosobranch Gasteropods, by J. P. McMurrich, with 4 plates, and on the anatomy and development of the Salpa-chain by W. K. Brooks, with 2 plates.

IV. Astronomy.

1. *Transactions of the Astronomical Observatory of Yale University.* Vol. I, Part I; New Haven, 1887, 4°, pp. 105.—The first piece of work undertaken by Dr. Elkin on taking charge of the Yale Heliometer in 1884 was the determination of the relative positions of those stars of the Pleiades which were bright enough to be measured by the instrument. This work has occupied the larger portion of his time during the last three years, and the present memoir is the outcome of it.

The stars measured were all of the stars in the Bonn Durchmustering down to the 9·2 magnitude, sixty-nine in number, which were in the dense part of the Pleiades group. One of the first undertakings of Bessel with the Königsberg Heliometer was the measurement of this group. He included 53 stars, one of which was, however, omitted by Dr. Elkin as being too faint. A comparison of two such measurements made with an interval of 45 years seemed likely to give results interesting and valuable of themselves. At the same time the methods employed were such as to furnish severe tests of the instrument, and to give due confidence to future properly conducted measures that shall be made with it.

Two separate and entirely distinct series of measures have been made. The first here presented was in time the second undertaken, being the measurement of the position, angles and distances from Alcyone. This was Bessel's method. It was not employed by Dr. Elkin until experience gave him confidence in the position angles determined by the instrument. The second was a system

of triangulation in which everything rested upon distances alone, and each night's work could be rendered independent of all changes of scale value due to temperature and other causes. Four stars were selected near the outer limits of the group forming angles of a quadrilateral nearly enclosing it. Outside of these and nearly in the extension each way of the diagonals of the quadrilateral four other stars were selected, and the positions of these latter were determined by meridian instruments at other observatories. The two lines of stars furnished the means of determining scale values and deducing absolute positions.

The distances of each star from the four angles of the fundamental quadrilateral were then measured, and these distances furnished equations for correcting assumed star places and scale values. The scale values were also independently determined by measures of the "Cygnus arc," a series of stars used for the same purpose in the transit of Venus observations.

These two series of observations were reduced, the resulting places compared with each other, and hence definitive places of the stars deduced for the epoch 1885·0.

The Königsberg measures of distances have been known to require changes by reason of errors of assumed scale values and temperature corrections. A new reduction of these measures is given by Dr. Elkin, and a revised table of places for the Bessel stars deduced for 1885·0 for comparison with the Yale places. The probable errors of the differences Y. - K. are computed, the mean value being $0''{\cdot}20$. Dr. Elkin considers twice this amount, or $\pm 0''{\cdot}40$, as a fair value to adopt, inside of which the actual motions are so likely to be mixed up with the errors of observation as to afford little clue to their real amount or direction. Above this limit of twice the probable error, if its estimate be correct, the large majority of the discrepancies are due to actual displacements. Of fifty-one stars compared nineteen fall below the limit $0''{\cdot}40$, while of thirty-two there is some considerable probability of displacement since 1840. A chart showing the apparent displacements is given, and Dr. Elkin says:

"The first fact which strikes the attention on examining these values of Y.—K. is, that for the six largest there is a remarkable community of direction and amount; these stars, shown on the chart with broken lines, are as follows:

		$''$		$''$		$''$
No. 14	Displacement in α:	−1·43,	in δ:	+2·15,	total:	2·52
17		−2·67		+1·28		2·76
21		−1·31		+1·32		1·78
26		−1·80		+1·16		2·01
35		−1·32		+2·23		2 54
36		−1·91		+1·19		2·12

and it is remarkable that this general direction of drift is very similar to the reversed absolute motion of Alcyone as given by Newcomb, namely, for forty-five years:

Reversed motions of Alcyone from Newcomb's Zodiacal Catalogue: } in α: $-0''{\cdot}92$, in δ: $+2''.47$, total: $2''{\cdot}61$

For two of the stars, Nos. 14 and 35, it seems to me the coincidence is, considering the uncertainty of the absolute motion of Alcyone, a quantity not easily to be estimated at present, quite close enough to warrant the deduction that these two stars at least do not belong to but form only optical members of the group. For the other four it will be admitted that there is some possibility, if not probability, that they also are only seen projected on the group.

"Of the remaining twenty-six of the thirty-two stars under consideration, it will be found that the distribution of the direction of motion is by no means equable, six stars only having an easterly motion, while twenty move towards the west.* And although it may prove to be fortuitous, and due to chance errors of observation, still it may be noted that there seems to be a tendency to community of drift in certain groups in the same part of the cluster, such as that formed by the stars 1, 2, 5, and 7, and that shown by Nos. 3, 4, 6, 9, and 10. A third group seems to be made up of the two sets 11, 12, 15, 20, and 31, 33, 37; and of the six stars with an eastward drift five, Nos. 19, 25, *s*, 34, and 39, are again about in the same direction. It is noteworthy that of the ten brightest stars only two are to be counted among the ones with some probability of displacement; and for these two, *b* and *m*, the divergences are very small, $0''\cdot49$ and $0''\cdot48$ respectively, confirming the conclusions reached by Professor Newcomb from the discussion of the meridian observations that the relative motions of the brighter stars are as yet in general insensible. For star *b*, however, I think the motion in declination is unquestionable; *m*, being only indirectly connected at Königsberg with Alcyone, is very much more uncertain.

"The general character of the internal motions of the group appears to be thus extremely minute. If for the six stars mentioned as with more or less probability not belonging to the group this proves to be the case, there are but five stars for which the displacement amounts to over $1''$ in forty-five years. The bright stars in especial seem to form an almost rigid system, as for only one is there really much evidence of motion; and in this case (star *b*) the total amount is barely $1''$ per century. The hopes of obtaining any clew to the internal mechanism of this cluster seem therefore not likely to be realized in an immediate future."

The work upon this group by M. Wolf at Paris, and at the University Observatory at Oxford is then compared with this at Yale: "The outcome of these comparisons appears to show that

* Lately, Professor Pickering, of Harvard, has photographed the spectra of the Pleiades stars, and it is of some interest to note that the only two marked divergences he has found among them are of two of the six stars having motions opposite to those of the generality of the group, stars *s* and 39, in which the K line is present. Star 25, which has a very similar motion to *s*, was unfortunately not determined on the photograph, on account of its spectrum falling over some of the others. Of the six stars which may very possibly prove not to belong to the group, they are all but one too faint in the photograph to have the character of the spectrum ascertained. The one, star 17, has the general spectrum of the group.

the use of the filar micrometer for such large distances as those under consideration is likely to be accompanied with considerable casual error, and, unless great care is taken, with large systematic error. The conclusions of Messrs. Wolf and Pritchard as to the relative motions in the group have thus been unfortunately vitiated, and must be replaced by those formulated at the end of the preceding section."

Another result of the discussion is that the probable errors of the heliometer measurements rapidly increase with the magnitude of the stars observed, so that Dr. Elkin expresses the purpose hereafter to restrict his investigations to stars which do not fall much below 8·1 or 8·2 magnitude, much as this will limit its field of activity.

2. *Annals of the Astronomical Observatory of Harvard College*, E. C. PICKERING, Director, vol. xvii. *The Almucantar; an investigation made at the Observatory in* 1884 *and* 1885; by S. C. CHANDLER, JR., Cambridge, 1887.—This volume of the Harvard Annals is devoted to the description and the theory of the new instrument invented by Mr. Chandler, and the results of observations and experiments with it. The almucantar consists of a telescope mounted upon a base that floats in mercury. The field is crossed by a reticule of horizontal lines, and one vertical line to mark the center of the field. The observation consists in noting the time of transit of a star across an almucantaral circle, such a circle taking the place of the meridian plane in meridian instruments.

Mr. Chandler considers it a fair conclusion from his experiments that the probable accidental deviation of the float from the mean position of equilibrium, is in the neighborhood of one-twentieth of a second of arc.

This mode of axial rotation of the sight line of the telescope he believes, therefore, to be nearer perfection than can be certainly attained by any instrument swinging on pivots in a vertical plane. If further investigations, especially with new forms of the instrument some of which are suggested by Mr. Chandler, shall confirm these conclusions, the almucantar seems certainly destined to be used for the solution of some of the most difficult astronomical problems.

3. *Parallax of α Tauri.* — Professor Hall has published in Gould's Journal the results of his measurements of *α Tauri* and its companion made in October and March last. Director von Struve had obtained the very large parallax of 0″·516. Professor Hall obtains, however, the small value of 0″·102. One series of Dr. Elkin's measurements of this star, made with the Yale Heliometer, indicates a small rather than a large parallax.

4. *Publications of the Morrison Observatory, Glasgow, Mo.*, No. 1, 4°, pp. 111.—The Morrison Observatory was established by a donation from Miss Berenice Morrison, and the present publication is prepared by the Director, Mr. Carr W. Pritchett. It contains a description of the observatory and its instruments, the

details of the determination of the geographic coördinates of the observatory, and a large number of miscellaneous observations. These have been made by the Director, by Prof. H. S. Pritchett, and by Mr. C. W. Pritchett, Jr. The principal instruments are a $12\frac{1}{4}$ inch equatorial, and a 6-inch meridian circle having 24-inch graduated circles.

V. Miscellaneous Scientific Intelligence.

1. *Bulletin of the California Academy of Sciences, January,* 1887.—This number of the Bulletin contains among its papers: G. F. Becker, on the Washoe Rocks; V. E. L. Greene, Studies in the Botany of California; R. Smith, on Tetraodon setosus; T. L. Casey, Descriptive Notices of N. A. Coleoptera; Dr. G. Davidson, on submarine valleys on the Pacific Coast; W. E. Bryant, ornithology of Guadalupe Island; G. Davidson, Early Spanish Voyages of Discovery on the Coast of California.

Guadalupe Island (29° 10′ N., 118° 18′ W.), is described as about 5 miles wide, 15 miles long, volcanic and having a reported height of 4523 feet. A ridge extends the whole length of the island, having steep slopes to the west. In January and December of 1885, Mr. Bryant found the climate cool, frost often at night, dense fogs frequent. The number of birds now known from this island is thirty-six. "Four of the 'straggling species,' Mountain Bluebird (*Sialia artica*), Varied Thrush (*Hesperocichla nævia*), Townsend's Sparrow (*Passarella iliaca Unalaschensis*), Golden-crowned Sparrow (*Zanotrichia coronata*), are recorded for the first time from so southern a latitude, while their presence so far off shore is of scarcely less interest." The Humming bird, *Trochilus Anna*, is one of the Guadalupe species.

2. *Technology Quarterly.* Vol. I, No. 1. 96 pp. 8vo.—This new scientific Quarterly, issued by the Massachusetts Institute of Technology, Boston, promises to be a very valuable Journal. It contains the results of work done by the students and officers of the Institute of Technology, which is one of the largest and best-equipped institutions of the kind in the country. The board of Editors is chosen from its Senior and Junior Classes, among whom Wm. S. Hadaway, Jr., is Editor-in-Chief. The subscription price is two dollars a year. This first number contains thirteen papers on technological, geological, chemical and other subjects.

3. *Meeting of the American Association for the Advancement of Science, at New York, commencing Wednesday, Aug.* 10.—The headquarters of the Association will be at Columbia College, and all the offices and meeting-rooms will be in the buildings of the College. The hotel headquarters will be at the Buckingham Hotel, Fifth avenue and Fiftieth street, one block from Columbia College. For all matters pertaining to membership, papers and business of the Association, address the Permanent Secretary at Salem, Mass., up to August 6. From Aug. 6 until Aug. 17, his address will be Columbia College, New York, N. Y. Arrangements for excursions and receptions will soon be announced.

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U. S. Geological Survey.

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ART. XI.—*History of the Changes in the Mt. Loa Craters;* by JAMES D. DANA. Part I, KILAUEA.

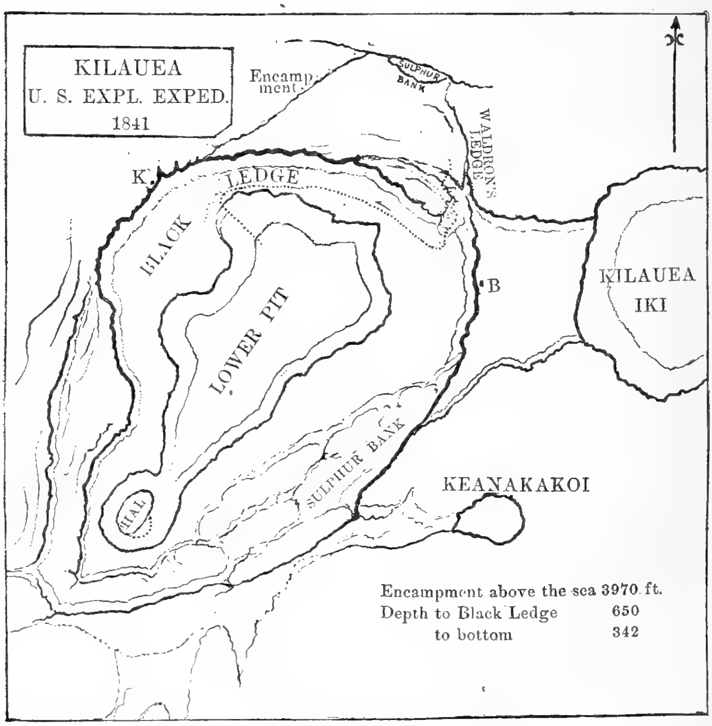
[Continued from page 451, vol. xxxiii.]

2. KILAUEA FROM JANUARY 1840 TO 1868 INCLUSIVE.

THE history of Kilauea thus far presented sustains the statement of my Expedition Report that three great eruptions occurred in the seventeen and a half years between the early part of 1823 and the summer of 1840, with intervals between of eight to nine years. The history reviewed also indicates that the method of change was, in a general way, alike for each interval, from the emptied state of the pit to that of high-flood level preparatory to discharge; and alike in the down-plunge of the floor consequent on the discharge. Further, the various accounts agree in referring the filling of the pit to outflows of lavas from lava-lakes, cones and fissures over the bottom of the crater, and in mentioning no facts that point to other concurring means.

During the following twenty-eight-year period, from 1840 to 1868, these several subjects received not only contributions of new facts, but the most fundamental of them, on the method of filling the pit, facts enough for a widened and apparently final explanation. Even within the first six years of the twenty-eight the demonstration was made out, though not published until 1851. The only down-plunge of the floor in this period, producing a lower pit, occurred at its close in 1868.

As the emptied state of the crater is the starting point for this second period of the history, and future changes have a degree of dependence upon it beyond what is generally understood, Wilkes's map is presented here in outline. It is reduced one-third lineally, and is so labelled as to bear its own explanations. The only additions are B, for Lord Byron's encampment, and K, for Kamohoalii, the highest point on the western wall. The scale of the reduced map is 5000 feet to the inch. The base of the upper and lower walls is indicated on it by a fine line. The position of this line in the lower pit shows a



wide divergence from Mr. Drayton's sketch (Pl. XII). My observations put the truth between the two; the walls were largely vertical, but had for long distances a high talus of lava blocks, to which additions were being made by frequent falls even eight months after the eruption. Only at one place was the descent from the black ledge to the bottom gradual, and this was on the northwestern side, where was a convenient way down.*

* See my Exped. Geol. Rep., p. 176. Captain Wilkes's map differs from Mr. Drayton's sketch also in the small width at the neck between the lower pit and Halema'uma'u. My impressions accord with the sketch, but are of no weight

(1.) *Changes in the Crater from* 1841 *to* 1849.—The changes after the year 1840 went forward in the usual quiet way, varying much from time to time, but on the whole with some increase in activity. In July, 1844, "the Rev. Mr. Coan was near when the large lake overflowed its margin on every side, spreading out into a vast sea of fire, filling the whole southern part of the crater as far as the black ledge on either side, and obliterating the outlines of the cauldron;"* and this was an example of what was often happening; but sometimes more extensively. Only two years afterward, in June of 1846, Mr. Coan reports† that "the repeated overflowings had elevated the central parts of the crater 400 or 500 feet since 1840, so that some points are now more elevated than the black ledge." This last statement implies that *in only six years, the lower pit, nearly* 400 *feet deep in June of* 1840, *had been almost or quite obliterated.* However extravagant it may seem it was true. In the course of the next month, July, Rev. Chester S. Lyman (afterward Professor of Mechanics and Physics in the Sheffield Scientific School of Yale University), visited the crater and found it in the condition reported by Mr. Coan. The account of his investigations which he published states‡ that "the whole interior of the pit had been filled up nearly to a level with the black ledge, and in some places 50 to 100 feet above it." Moreover, Mr. Lyman proved that the change was not a change of level in the ledge, instead of the center of the pit, by measuring a base and taking, with a quadrant, the altitude above it of the high western wall, making it 680 feet, which agrees very nearly with the result of Wilkes's measurement.

Beyond all this, Mr. Lyman obtained full testimony as to *the way in which the rapid obliteration of the pit had gone forward.* He found that while the bottom of the pit was almost level with the "black ledge," there was upon it, *along the inner margin of the ledge*," "a continuous ridge more than a mile in length consisting of angular blocks of compact lava, resembling the debris at the foot of a range of trap or basalt," and that this ridge had a height "on its outer or eastern face often of 50 or 100 feet [above the ledge], especially toward the south part,

against a survey. The crater Kilauea-iki is not named at all in Wilkes's map, unless "Lua-Pele" (a name of Kilauea) is intended for it. Mr. Wm. T. Brigham, on page 25 of this volume, expresses his confident opinion that the name Kilauea-iki (Little Kilauea) has become fastened to the wrong one of the two eastern pit craters. But it is used as here on the recent government maps, and was so used by Ellis in the earliest account of the crater; and it is the one of the two craters that is large enough to be so contrasted with Kilauea.

* My Expl. Exped. Report, p. 193. † Ibid.

‡ This Journal, II, xii, 75, 1851. A letter from Mr. Lyman, dated Sandwich Islands, July, 1846, is referred to on page 193 of my Expedition Geological Report, but no facts respecting the crater are there cited except the one that some parts of the center stand 100 to 150 feet above the black ledge; I have no knowledge of what it contained beyond this.

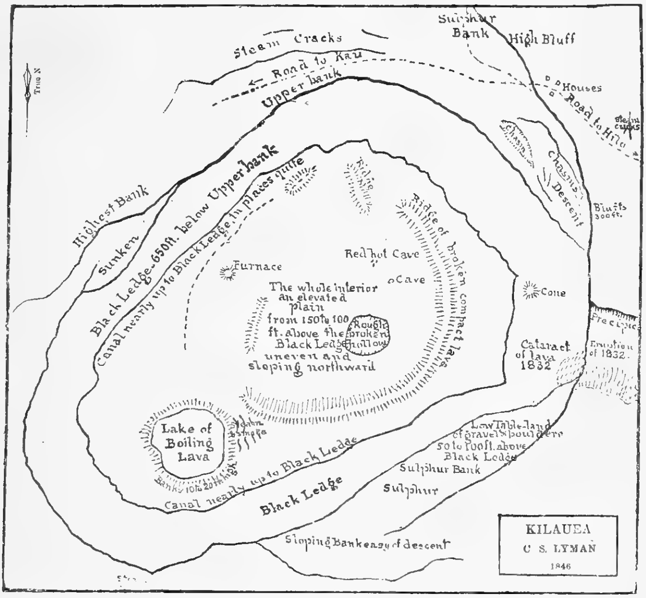
where it approached the Great Lake." Another remarkable feature of related import, was the existence generally of a trough, or "canal" as it had been called, between the ridge and the margin of the ledge, "several rods in width and in some places 40 or 50 feet in depth." The ridge looked highest from the black ledge side, the ledge being lower than the interior plain. Following it southward, the slope on the interior side diminished in height, and finally run out, while on the black ledge side, the elevation increased until the slope became a precipice over 100 feet high, which was so steep at "its southeastern limit that stones hurled from the hand cleared the foot of the bluff." The stones were "nearly three seconds in falling, which would give for the perpendicular elevation the amount just stated," [or between 140 and 150 feet.]

The "canal," as was learned from Mr. Coan, had been filling up, from a previous depth of 200 feet, by flows of lava from the Great South Lake. On one occasion the lake, "filled to the brim," poured out two streams, from "nearly opposite points of the lake," which followed the broad canal of either side, fifty or more feet deep and wide, "until they came within half a mile of meeting under the northern wall of the crater, thus nearly enclosing an area of about two miles in length and a mile and a half in breadth."* In 1846, it was nearly filled, and in some parts entirely obliterated.

After a survey of the facts as to the position and nature of the long ridge of lava blocks and comparing with the condition in 1840, Mr. Lyman concluded that the ridge "once constituted a *talus*, or accumulation of debris," on the floor at the foot of the walls of the lower pit of 1840; that the floor with its margin of blocks had "been elevated, partly by upheaving forces from beneath, and partly by overflows from the Great Lake and other active vents," until the talus overtopped "the precipice at the foot of which it was accumulated." He adds: "The phenomenon seems inexplicable on any other hypothesis than that of *the bodily upheaving of the inner floor of the crater.*" "When visited by the Exploring Expedition in 1840, the surface of the Great Lake was between three and four hundred feet below the black ledge and measured only 1000 by 1500 feet in diameter. Consequently in six years the lake had not

* Coan, Life in Hawaii, 1882, p. 263. Mr. Coan does not give the date of the event here mentioned; but no such "canal" is in the record except that of 1846. The time of the first recognition of the canal is not stated. It is certain that the "two deep fissures" of July, 1844 (Coan, this Journal, II, ix, 361, and my Exped. Rep., p. 193), were not the two sides of the canal; for they were opened "*under* the black ledge" and encircled "the whole *southern* area," while the Lyman canal encircled the whole interior of Kilauea. Further, as Mr. Coan says, these fissures around the southern area soon became filled with lava that was pouring over from the lake; while the "canal" was to a large extent unfilled in 1846.

only increased in size, but it had actually risen in height as much as it had been previously depressed by the out-draining of lavas in the eruption of 1840. This gradual rising of the solid embankment of the lake cotemporaneously with the lake itself, together with the filling up of the whole interior of the crater, is doubtless to be attributed to the combined effect of repeated overflowing together with the upheaving agency of subterranean forces."



Mr. Lyman took a few compass bearings in the crater, and some angles with a quadrant which he had constructed for the Kilauea visit, and left, with a friend on the Islands, a rapidly penned sketch of the crater showing the general condition of the interior. A reduced copy of the map with its lettering is here given. The chief discrepancy between it and the description is in the large interval between the "ridge" and the "canal," the latter being too near the outer wall. The "ridge," as is seen, is made to extend through half the circumference of the lower pit. The "Furnace," marked on the map, is described in his paper as oven-like, ten or twelve feet high, with walls a foot thick; as being inactive but showing within a glowing white heat early in July, but "in full blast" at his second visit in August, six weeks later. The large depression in the crater, which contained steaming fissures and chasms, appeared to have been the site of a former lava-lake.

The crater at the time of Mr. Lyman's visit was moderately active. The diameters of the Great Lake were 2400 and 2000 feet. Over its surface, ten or fifteen feet below the brim, on which he stood, the lavas were in gentle ebullition, tossing up broken jets 5 to 15 feet, and passing through frequent transitions between a crusted and a wholly molten state. It is evidence of relatively feeble activity that, standing on the brink, a handkerchief before the face was sufficient to shield it from the heat. In November of 1840, it was hardly possible to walk on the black ledge abreast of the lake, on account of the intense heat and light. The lavas had a general movement to the southwest. "A large stick of wood thrown on the lake, at a point where the ebullition produced a sort of eddy or rolling in of the lava, was immediately taken out of sight; but the next instant a more violent ebullition with a sudden outburst of flame and smoke told how, almost instantaneously, the stick had been transformed into charcoal."

The following year, in July, the Great Lake was boiling in much the same way as in 1846, with the liquid lavas still accessible, so that portions were taken out with canes.*

Early in 1848 the lake was the most of the time unusually inactive and became, as Mr. Coan states,† thickly encrusted over. The solid crust was soon after raised into a dome 200 or 300 feet high, covering the whole lake. By August, the dome was almost high enough "to overtop the lower part of the outer wall of Kilauea and look out upon the surrounding country." The fires within were visible through fissures; and occasionally lavas were ejected in sluggish masses, or forcibly, from several apertures or orifices of the dome, which "rolled in heavy and irregular streams down the sides," spreading and cooling over the slopes or at the base. "The dome, as it now stands," Mr. Coan wrote, "has been formed by the compound action of upheaving forces from beneath, and of eruptions from the openings forming successive layers upon its external surface."

This is the first account of a dome over Halema'uma'u; and the description and explanation of it agree with accounts of the most recent. During the most part of the year 1848, "no fire was to be seen in Kilauea, even in the night."

(2.) *Eruption* (*probably*) *of* 1849, *and changes from* 1849 *to* 1855.—After the events just mentioned, no important change in the crater is mentioned before the spring of 1849, when in April and May there was a return to great activity, and startling detonations were heard from the cones about the dome. The lavas were projected to a height of 50 to 60 feet from an opening in the top of the dome, and moreover the action

* Coan, this Journal, II, xii, 80, letter of Jan., 1851. † Coan, ibid., p. 81.

became so violent elsewhere that "travellers feared to descend into any part of the crater." This state of unusual activity was such as foreboded an eruption. It suddenly ceased, and probably by a subterranean discharge. It left the central plateau and the dome undisturbed; but the lavas were gone from Halema'uma'u and steam and vapors were the evidence left as to fires beneath.

A time of unusual quiet, of "steaming stupefaction," followed, and continued on through 1850 and 1851.* Early in 1852, the orifice at the top of the dome was 100 feet across and boiling lavas were seen within.† By July, this orifice had increased to 200 feet; and it was still enlarging by falls of great masses into the abyss 150 feet below, while steam and smoke were escaping from many holes in the sides of the dome, and lavas were ejected through a fissure dividing the west wall from top to bottom. Elsewhere the interior of Kilauea had little changed.‡ Mr. Coan predicted the speedy engulfment of the falling dome; but in the latter part of 1853 it was still standing, and probably was two miles in circuit, with a height of 300 to 600 feet.§

The great central plateau, surrounded by what used to be called the "black ledge" continued rising, and in 1853, its surface by Mr. Coan's estimate, was 600 feet above the bottom of 1840, and in part 200 feet above the ledge. His letter says "rising is going on" "first by the lifting forces below," "second, by eruptive overflowings; the former is more uniform and general, the latter, irregular and partial;" the former "in some places gradually, in others abruptly." Lyman's ridge of lava-blocks still existed little changed.

The crater continued "unusually dull" through 1854. The central plateau had been long out of reach of the fires, and ferns and Ohelo bushes were growing on it.

3. *Eruption of* 1855.—In 1855 a change to unusual activity occurred.‖ The lavas underneath the dome commenced throwing up jets to a height of 200 feet; vents were opened over the surface of the old black ledge; and thus in May and June the great central plateau had a girdle of fires nearly half a mile wide, in which Mr. Coan says he could count 60 lakes of "leaping lavas." There was one great lake at the foot of the north-

* Coan, this Journal, II, xiii, 397, 1852.

† Coan, ibid., xiv, 219, 1852, letter of March 5, 1852.

‡ Coan, ibid., xv, 63, 1863, letter of July 31, 1852.

§ Coan, ibid., xviii, 96, 1854, letter of Jan. 30, 1854. "The Island World of the Pacific," by Rev. Henry T. Cheever (8vo, New York), appeared in 1851, with an account of a visit to Kilauea. But the descriptions give no information of value, and the two plates relating to Kilauea (at pp. 287 and 307) are from Wilkes with large modifications in one and no acknowledgments; and with no statements that the view of the crater is an 1840 view—not 1850.

‖ Coan, this Journal, xxi, 100, 1856, letter of July 18, 1855, and p. 139, letter of Oct. 15, 1855.

east path down into the crater, and other "boiling caldrons" not far distant, so that access to the pit was cut off. The crater seemed to be ready for another eruption. On October 9th, the crater was still active, but less intensely so; the dome over Halema'uma'u had fallen in.

Mr. Coan's report of March, 1856, mentions several visits to the *summit-eruption then in progress*, but nothing about Kilauea until October of that year, when he speaks of the crater* as declining in activity for the year past, since the summit eruption began; "getting more and more profoundly asleep;" "only a little sluggish lava in the great pit of Halema'uma'u but much escaping vapor." A subterranean discharge took place probably in October, 1855.

4. 1855 *to* 1864.—In June of 1857 Kilauea was still quiet.† The lavas of the Great Lake were but 500 feet across and 100 feet below the edge. The alternations from the crusted to the completely molten state *took about three minutes.*

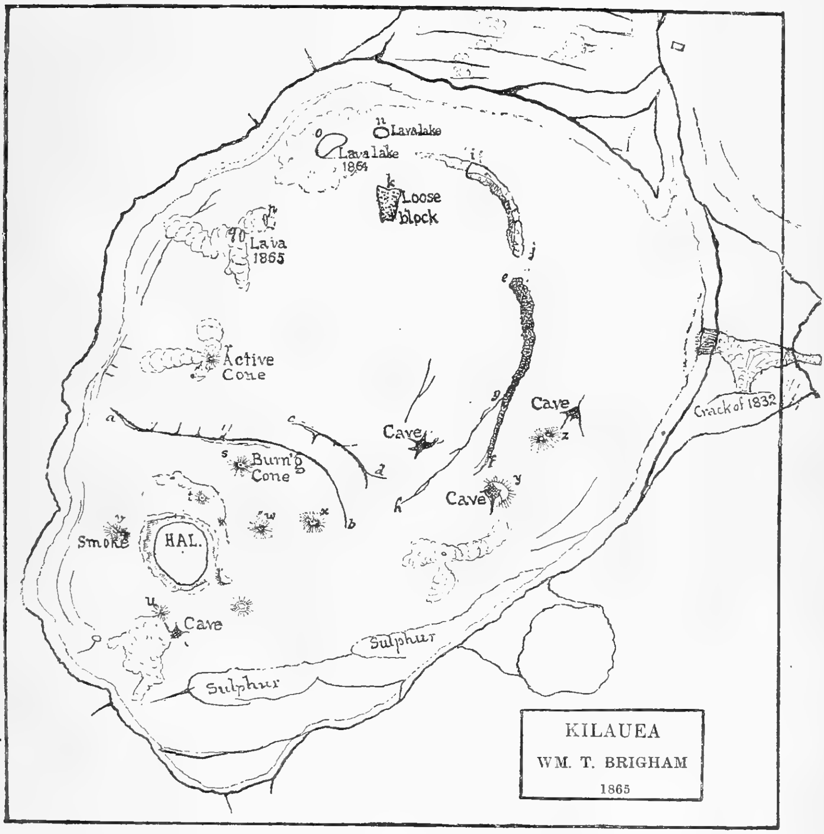
Through the following year, as during the two preceding, there was little change. In August, 1858, the Great Lake, some 500 feet in diameter, "boiled and sputtered lazily at the center of a deep basin which occupied the locality of the old dome." The action alternated between general refrigeration and a breaking up of the whole surface with intense ebullition."‡

In 1862, the condition was but little different. Halema'uma'u had a lake at center "about 600 feet in diameter." Within the basin, a fourth of a mile from the border of the lake at its center, there was a large mound of lava [a blow-hole product] with pinacles and turrets, somewhat cathedral like.§ In the summer of 1863,‖ activity had not much increased; at *intervals of a few seconds to half a minute*, a large fountain broke forth at the middle of the lake throwing up a rounded crest of lava 10 to 12 feet, and smaller portions to a height of 20 to 30 feet, while elsewhere there was a filmy crust through which small stones thrown in sank; and then again there was ebullition at various points in the lake: facts showing that the action was still far from brilliant.

In October, 1863, Mr. Coan reported new activity in the Great Lake, and through the whole circumference of the crater, with outflows that covered the old black ledge with fresh lavas. But the central plateau, "a distinct table-land," probably 500 to 600 feet above the bottom of 1840, remained unchanged.¶

* Coan, this Journal, II, xxiii, 435, 1857, letter of Oct. 22, 1856.
† Coan, ibid., xxv, 136, 1858, letter of Sept. 1, 1857.
‡ Coan, ibid., xxvii, 411, 1859, letter of Feb. 3, 1859.
§ Coan, ibid., xxxv, 296, 1863, letter of Nov. 13, 1862.
‖ O. H. Gulick, ibid., xxxvii, 416, 1864, letter of July 25, 1863.
¶ Coan, ibid., xxxvii, 415, 1864, letter of Oct. 6, 1863.

5. 1864–1866. *Observations and Map of* Mr. William. T. Brigham.—In 1864, Mr. Brigham visited Hawaii and began the observations on its volcanoes reported in his memoir. The accompanying copy (reduced) of the map made by him from his survey in 1865, deserves special attention. The map confirms the statements, made from 1846 onward, as to the obliteration of the lower pit. It shows the southwestern sulphur banks of much diminished extent since 1840, from lava over-



flows. Halema'uma'u has apparently its old position, or is very near it. There are also, on the map, other lakes of small size; cones, two or three of which were of blow-hole origin, and one, *e*, named the Cathedral, from its half a dozen turrets (figured on p. 423 of the memoir) is that mentioned in 1862 by Mr. Coan (p. 88).

The map shows also two long pieces (*e f*, *i j*,) of Lyman's ridge of loose blocks of "compact broken lava," "concentric"

as Mr. Brigham reports, "with the main wall of Kilauea" "marking the limits of Dana's black ledge" [that is the black ledge of 1840]; "composed of fragments of all sizes and shapes, very solid and heavy, and full of small grains of olivine."

A recent letter from Mr. Brigham informs the writer that the ridge *i j* (which is not particularly mentioned in the report) had the same constitution as *e f*, but consisted of larger blocks.

Other interesting features, indicated on the map are (1) a wall, *a b*,—fault-wall—enclosing an amphitheatre, that of the Hale-ma'uma'u region, perhaps a result of a discharge at some unrecorded time of the lavas of the lake; (2) just north of this, a deep fissure *c d*, concentric with the wall *a b*; and (3) warm or hot steaming caverns in the floor of the crater, some of which were hung with gray-black, often tubular stalactites."*

The text states that in 1864 the "black ledge" region was fifty feet below the level of the interior plain of the crater, and that the difference in level was the same in May, 1866, although both had been much raised, "at least a hundred feet," the former by overflows and the latter without overflows.*

Mr. Brigham does not allude to Mr. Lyman's explanation of the long ridge of lava-blocks. He remarks as follows on p. 421, after stating the constitution of the ridge, as already cited: "This wall, which is concentric with the main wall of Kilauea, is said to rise and fall and sometimes disappear, which seems to be a fact, although no one has ever seen it in motion. It is the fragments broken from the edge of the crater by an eruption and floated out to its present position." Again, p. 415, "From a manuscript map prepared by Mr. Lyman, I find the ridge occupied the same position as at present." Again, in his account of the crater in May, 1866, p. 427: "The ledge of broken lava which swept around the eastern end of the crater, marking the limits of Dana's black ledge, is nearly covered with the successive overflows."

The Great Lake had a diameter of about 800 feet in 1864, and of 1000 in August, 1865. Its lavas in 1864 were 50 feet below the edge, and extended into caverns beneath it. The action was mostly feeble, "occasionally a crack opened and violent ebullition commenced at several points; again it was liquid, but soon passed to the viscid condition; again "boiling violently and dashing against the sides, throwing the red-hot spray high over the banks." There were two small islands in the lake in 1864; but in August, 1865, they had disappeared, and the lavas were then only 30 feet below the edge.

* The composition of the material of the stalactites, as given in the text, p. 463, from an analysis by Mr. John C. Jackson, is: Silica 51·9, alumina 13·4, iron sesquioxide 15·5, MnO 0·8, lime 9 6, magnesia 4·8, soda 3·0, potash 1·1=100. Specific gravity 2·9. The temperature of the caves was usually 80°–95° F.

The existence of flames over the large boiling lake is attested to by Mr. Brigham, who says (p. 423) speaking of a midnight view, that "they burst from the surface, and were in tongues or wide sheets a foot long and of a bluish green color, quite distinct from the lava even where white hot. They played over the whole surface at intervals, and I thought they were more frequent after one of the periodical risings of the surface."

In 1866,* there was a great increase of activity in Kilauea in May, June and July, beginning just after the cessation of the summit eruption. In May, new lakes of fire and cones were opened along a curving line extending from the Great Lake northwest to north and northeast, thus again covering the "black ledge" portion of the crater, flooding the surface with lavas for a distance of four miles, and with a breadth in some places of half a mile; and for days the flood of lavas closed the usual place of entrance to the crater. Large blocks were shaken down from the walls of Kilauea; and Mr. Brigham observes that these blocks were soon removed by the intensely active flood at their base, "showing how pit craters may be enlarged horizontally." In August the force of the eruption seemed to be spent—but no subterranean outflow is known to have occurred. During all the activity the central plateau of the crater remained undisturbed.

6. *Eruption of* 1868.—In 1868 a great outbreak and down-plunge took place in Kilauea, almost simultaneously with an erruption from the summit-crater of Mount Loa.† It was preceded by a succession of heavy earthquakes—two thousand or more according to reports—commencing on the 27th of March and culminating on Thursday, the 2nd of April, when a shock occurred of terrific violence, which was destructive through the districts of Hilo, Puna and Kau, northeast, east, south and southwest of Mt. Loa, and was felt far west of the limits of Hawaii. With the occurrence of this great shock, fissures were opened from the south end of Kilauea southwestward through Kapapala, a distance of thirteen miles, and bending thence southward toward the coast. The position of this line of fissures is shown on the large map of Hawaii published by the Government Survey in 1887; it followed the course of earlier fissures. Some lavas were ejected from the openings in Kapapala, which were probably lavas from Kilauea. Simultaneously with the

* Coan, this Journal, II, xliii, 264, 1867; Brigham's Memoir, p. 427.

† Dr. Wm. Hillebrand, this Journal, II, xlvi, p. 115, 1868; Coan, ibid., 106; F. S. Lyman, ibid., p. 109; H. M. Whitney, ibid., p. 112; Coan, ibid., xlvii, 89, 1869, letter of Sept. 1, 1868, with a map of southern Hawaii on p. 90. Also the same letters in a paper by Mr. Wm. T. Brigham, in the Memoirs Bost. Soc. N. Hist., i, 564, with a map on p. 572. The map was made by Mr. Brigham from his survey in 1865 and the descriptions of the 1868 eruption.

violent shock, a decline began in the fires of Kilauea. By night of that same Thursday, the liquid lavas had disappeared from all cones and were confined to the lakes; by Saturday night, all the lakes were emptied except the Great Lake; finally, by Sunday night, the 5th, the Great Lake had lost its lavas, and all was darkness and quiet. A down-plunge of the central plateau of the crater took place at the same time, so that again a lower pit existed, as in 1840. Mr. Coan, in describing it, says that the plateau "sagged down" 300 feet; and another writer, after a visit to the pit, gives the same depth and remarks "just as ice falls when the water is drawn from beneath." The great sunken area had not vertical walls, like that of 1840, but sloping sides as the term "sagged" implies; the slope, generally 30 to 60 feet, but at a much less angle on the side toward Halema'uma'u. There was again a black ledge, and it was nearly of its old width, but at a somewhat higher level owing to the overflows. The emptied Great Lake, 3000 feet in diameter at the top, 1500 feet below, and 500 feet deep, was literally empty; it showed no light at bottom by day and not much at night. The discharge of lava may have been as great as in 1840, although the lower pit made by the undermining had less extent.

Another remarkable fact is stated that just before the earthquake of the 2nd of April, "the lavas of Kilauea burst up vertically in Little Kilauea (Kilauea Iki), and spread over the old deposit of 1832."

On Tuesday, April 7th, five days after the beginning of the Kilauea discharge, the lavas were ejected in great volume at Kahuku in southwestern Hawaii, and flowed to the sea. It was at first a question whether a part of the Kahuku flow might not have come from Kilauea. But the extinction of the summit fires occurred at the same time, and the Kahuku discharge was in a line with fissures leading toward it from the summit, so that Mokuaweoweo is believed to have been their only source. The conduit of the Kilauea lavas, was probably ruptured at the time of the great shock, and hence the discharge.

The curving of the Kilauea fissures from Kapapala toward the coast seems to point to a submarine discharge off that part of the island.

3. Kilauea from 1868 to 1886.

This period of eighteen years passed without another down-plunge of the floor of the pit. The gradual filling of the new-made lower pit, and the ultimate merging of all slopes at the crater's bottom into those leading off in all directions from Halema'uma'u, are the chief events of the period. Mr. Lydgate's map on page 94, shows an intermediate stage in the progress.

1. *Changes from* 1868 *to* 1879.—After the discharge and consequent exhaustion of 1868, Kilauea was slow in its return to activity. In July of 1869, Mr. Coan found the crater quiet, and the basin of the Great Lake so nearly cooled that he went down into it, measured across its bottom 400 feet below the rim, finding it "five-sixths of a mile" wide, and at top more than a mile from the north to the south side. Down fissures over the emptied basin he could see the lavas, 50 to 100 feet below, still in ebullition.* Two years later† the Great Lake was full, and successive overflowings had covered deeply the southern end of the crater and sent streams two miles northward, filling the central pit to a depth of fifty feet. In August of 1871, Halema'uma'u was again a deep cavity, hot and full of dense vapors;‡ but before August of 1872, it was full with lavas and often overflowing into the great basin of 1868.

On March 3, 1873, Halema'uma'u, according to Mr. Nordhoff,§ was divided between two lakes, their shorter diameter about 500 feet; "the two were separated by a low-lying ledge or peninsula of lava; each was red, molten, fiery" within. From the "north bank" the depth of the pit or basin to the lavas was seen to be about 80 feet, and "the two large lakes appeared to be each nearly circular."

In January, 1874, says another observer, the lower pit was still much below the ledge. The surface of the Great Lake was 35 to 40 feet below the edge of the basin, and "possibly" 500 feet, by nearly half a mile in its diameters, but divided almost in two by a low bank of rock. Four months later, on the 4th of June, the cone about the Great Lake had risen much, and the lake was divided through into two oblong lakes, a north and south, in the direction of the longer diameter; it lay below precipitous and partly overhanging walls 80 feet high. The action was less intense than in January. There were active cones near by; 100 yards from the lake, one typical blowing cone "of beehive shape," 12 feet high, about 40 feet deep within, and having walls two feet thick, which was throwing up jets and clots of lava through holes in its sides, "with a deafening or rather stunning roar" and subterranean rumblings and detonations.‖

The following is a reduced copy of a map by Mr. J. M. Lydgate, made probably in June of 1874.¶ It has great interest,

* Coan, this Journal, III, ii, 454, letter of Aug. 30, 1871, and xviii, 227, 1879.

† Coan, ibid., ii, 454, 1871.

‡ Coan, ibid., iv, 407, 1872. Letter of Aug. 27, 1872.

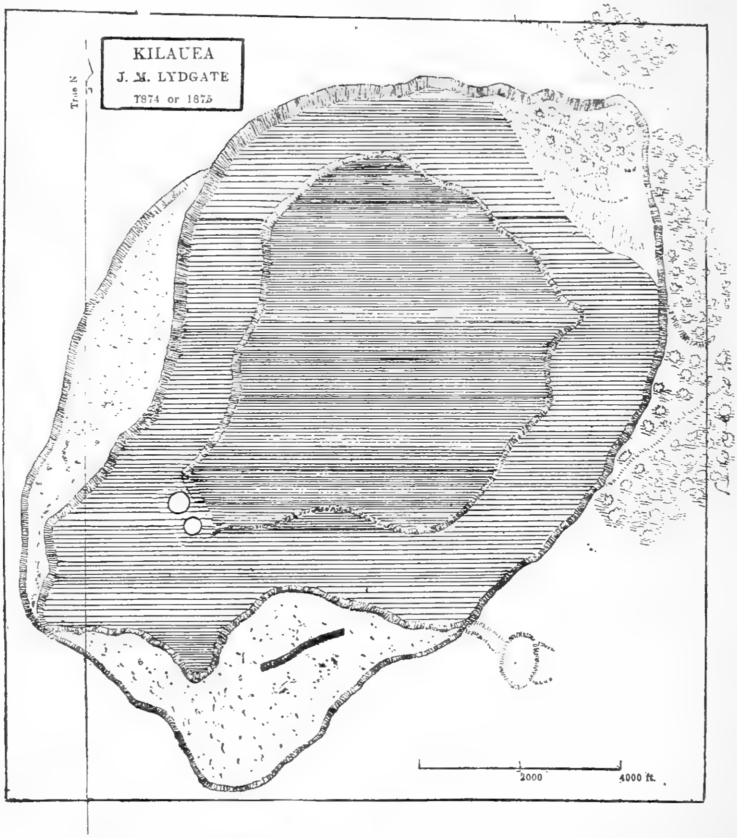
§ Northern California, Oregon and the Sandwich Ids. London, 1874.

‖ Isabella L. Bird, the Hawaiian Archipelago, London, 1875, pp. 55, 253.

¶ For this tracing I am indebted to the Surveyor General, Mr. Alexander, the original being in the archives of the office of the Hawaiian Survey. It is stated on it that the map was made either in 1874 or 1875, and probably in June, 1874.

since it shows the central depression or pit of 1868 still well defined, and also the subdivision of Halema'u'ma'u, above alluded to.

Mr. Coan states, early in October of 1874, that "the great central depression of 1868 has been filled up by deposits about 200 feet," and that the region around the Great South Lake was a truncated elevation nearly as high as the southern brim of the crater.*



2. *Eruption of* 1879.—In 1879 (April ?) Kilauea was again in eruption;† for the Great Lake, which had been running over, and whose rim had been raised till nearly as high as the outer edge of Kilauea, was suddenly emptied by a subterranean outlet and subsided several hundred feet, leaving nothing but a smoking basin.

* Coan, this Journal, III, viii, 1874, letter of Oct. 6, 1874.
† Coan, ibid., xviii, 227, 1879, letter of June 20, 1879.

After some days, in which there was no evidence of fires except that from escaping vapors and steam, the lava reappeared; and before May, 1880,* Halema'uma'u had again become a boiling and overflowing lake, pouring its streams into the great central basin of the crater.

In July of 1880, Mr. Wm. T. Brigham was again at the crater.† By barometric observations he made the depth to the northeast margin of the floor of the crater at the foot of the place of descent 650 feet below the level of the Volcano House; and the higher central portion of the floor, which was dome-shaped, was found to be 350 feet above the northeast margin, making the flat dome 350 feet high.

The "tolerably regular dome" was "surmounted by four lakes of an average diameter of a thousand feet." The latest of the four, the southeastern, commenced to form May 15th of that year, and its bank was in part nearly on a level with the lavas; but the others had stratified walls, as is stated and figured, which were in places 100 feet or more in height, and from their front there were frequent avalanches owing to the undermining action of the active lavas beneath. These lavas were seen here and there to be white-hot in the night view. In the darkness, "a large volume of gas" was observed escaping from a cluster of blow-holes in the vicinity of the lakes, "which burned with a bluish green flame," differing in its continuance from the flames seen before by Mr. Brigham, which "seldom lasted longer than a few moments."

The four lakes replaced old Halema'uma'u. By sighting from two of his monuments left from the 1865 survey, Mr. Brigham obtained evidence that the area of the old lake lay "in the midst of the present four lakes" instead of corresponding with either of them. This would make the summit, of the dome to be in the Halema'uma'u part of the crater, or its southern portion, as in 1886, the dome having in fact "a very eccentric apex."

In 1882, Captain Dutton made his examination of Kilauea. He states that after reaching the floor of the crater, he walked over the uneven surface for about a mile and three-quarters, and then came to a rapidly ascending slope, rising about 100 feet; and from the top of it looked down on "New Lake," about 480 feet long and 300 feet in width, lying between walls 15 to 20 feet high, situated to the northwest of Halema'uma'u. This lake first appeared, he states, in May, 1881.‡

* Coan, this Journal, III, xx, 72, 1880; letter dated May 3–6, 1880.

† This volume, p. 19, 1887.

‡ This Journal, III, xxv, 220, 1883, letter of Feb. 8, 1883; and U. S. Geol. Report, loc. cit.

New Lake was much of the time crusted over, showing fires only at the edges; break-ups, making cracks over the whole surface, and followed by an engulfing of the numberless fragments until "the whole was one glowing mass of lava," occurred at intervals of forty minutes to two and a quarter hours; but they were of short duration, and the lavas in the mean time were "quite black and still." Now and then a fountain broke out in the middle of the lake and boiled feebly for a few minutes; then it became quiet, "but only to renew the operation at some other point." The larger and more active lake, Halema'uma'u, half a mile off, was surrounded by a cone of loose lava fragments, the lavas a hundred feet below the top. The lake was to a considerable extent crusted over; but there were boiling fountains of liquid lava five to ten feet high (by estimate) in play, changing their positions from one part of the lake to another; one dying out as another started up. Two masses of solid lava were seen in the New Lake, looking as if formed in it, which in the course of several days shifted their positions, showing that they were floating islands.

3. *Eruption of* 1886.—These conditions continued, though with great variations, until March of 1886. On the 6th of that month, both Halema'uma'u and the "New Lake," (See Plates I and II, last volume), the latter five years old, were unusually full and active, and mingled their floods in overflows. The next morning, between 2 and 3 o'clock, the lavas disappeared and left both basins empty—first, the shallower New Lake, and then the Great Lake. The cone around the latter, then 200 feet in height above the boiling surface, fell into the emptied basin, and for days the down-plunge of the walls continued. The emptied basin, according to the measurements reported by Mr. Emerson, was about 2,500 feet in mean diameter, 560 feet in depth at center, and 200 feet in the depth of the precipitous sides except on the south. Mr. Emerson's map, Plate I of the preceding volume, represents the basin in its condition of exhaustion, and New Lake with its stranded floating island, standing 60 feet above its base. The map further shows, and also Plate II, by Mr. Dodge, that the great central basin of Kilauea, the lower pit of 1868, had been wholly obliterated, and all signs of the old black ledge. The lavas in the later years had swept over the whole surface, and placed Halema'uma'u at the head of all the slopes of the bottom, both the northern and the southern. The area around this lake-basin was left, as the map of Mr. Emerson shows, 350 feet below the level of the Volcano House, the center of Kilauea 356 to 400 feet below, and the bottom near the place of descent 450 to 485 feet. Mr. Emerson remarks, moreover (and the map indicates the same), that, with only a little more rise, the lavas of Halema'uma'u would discharge over the top of the southwest wall of Kilauea.

In July, four and a half months after the discharge, as Mr. Van Slyke reports, the emptied basin of Halema'uma'u contained within "a rising cone of loose rocks." The cone surrounded the central part of the basin, and consequently a great and deep trough-like depression several hundred feet wide separated it from the walls; it had a height in most parts of "perhaps 150 feet," and small cones and basins of lava existed at points in the trough around it.

Mr. Dodge's map and article (p. 99 of the preceding volume) represents the rising cone as 930 and 1,100 feet in its diameters, and as having some points in its summit as high as the edge of the basin—its condition in November, eight months after the eruption. Still later, in January,* he represents the cone of fallen blocks and lava debris as "perhaps 200 feet" above the height in October, and speaks of the rising as going on "slowly, *as though floating on the surface of the new lava-lake.*"

A "review of the phenomena, with conclusions" will complete this account of the changes in Kilauea since 1823; and, in the mean time, I hope to see the crater, in order better to understand its present and past condition..

[To be continued.]

ART. XII.—*On some phenomena of Binocular Vision*; by JOSEPH LECONTE.

NO. XII.—*Some peculiarities of the phantom images formed by binocular combination of regular figures.*†

[Read before the National Academy of Sciences at Washington, April 22, 1887.]

THE law of corresponding points is justly regarded as the most fundamental law of binocular vision. Properly understood it explains every phenomenon; and no field of investigation can be more fascinating than to trace, on the one hand, deductively the logical consequences of this law in resulting phenomena, and on the other, inductively the phenomena back to this law as their sufficient cause. The phenomena now about to be described, and to be explained by this law, have some of them not been heretofore described and none of them satisfactorily explained.

It is well known that the figures of a regularly figured plane, such as a tessellated floor or a papered wall of regular pattern, may be combined by crossing the eyes, or (if the figures be not

* This Journal, xxxiii, 240, letter to the writer, dated Jan. 27, 1887.

† For other papers on the same general subject see this Jour. 1868–1880.

too large, i. e. not farther apart or much farther apart than the two eyes) by looking beyond the plane of the figures as in the stereoscope, so as to make phantom-images, which may seem to the observer as distinct as the object itself. The combination by *crossing* is by far the easier, and it is this method therefore which we shall use in all the following experiments. As in this case the phantom image is always at the point of sight, i. e., where the optic axes meet, it is evident that by combining first contiguous figures, and then by stronger convergence those more and more distant from each other, the phantom-plane is brought nearer and nearer to the eyes, until by extreme convergence it may be brought within a fraction of an inch of the root of the nose. A tessellated pavement or oil-cloth may be thus brought up as phantoms successively through many different planes (the number depending upon the size of the figures) almost to contact with the face. Then by relaxing the converging muscles, the phantom-image may be let fall and caught on successively lower planes until finally it is dropped to its natural place and becomes *real.* Of course since the angular diameter of the figures remain the same, the *apparent* size becomes smaller as the phantom-image comes nearer. The phantom may thus become the most exquisite miniature imaginable. If on the other hand we combine by looking beyond the plane of the object as in the stereoscope, the phantom-figures are proportionally enlarged. The phantom is usually represented as a plane. Such it would be by geometric construction, but such it is not in reality as we shall presently show.

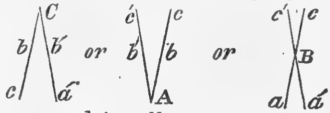
The foregoing experiments are to me as easy as natural vision, and the resulting phantom as distinct as a natural object. Most persons, however, will find some difficulty in making the phantom clear; because the eyes are accommodated to nearer distance, viz: the point of sight, while the light comes from a greater distance, viz: from the real object. In such cases the use of slightly concave spectacles will remedy the difficulty.

I recall these well-known facts to mind only that what follows may be readily understood.

Experiment 1.—I sit in a chair in the middle of a regularly tessellated floor and direct the eyes on the floor at an angle of about 45°. By ocular convergence I now combine successively the figures of the floor, stopping a little while after each combination until the phantom-image becomes perfectly clear. These phantom-floors are distinctly perceived to be *not horizontal* as they ought to be by geometric construction, *but inclined;* dipping away from the observer at higher and higher angle in proportion as, by greater convergence, the phantom-floor comes nearer and nearer. I am sure I can easily make the apparent slope 30°–40°.

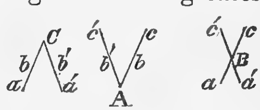
In addition to the slope of the phantom-plane, another phenomenon is plainly perceived; the figures change their shape, being all *elongated* in the direction of the slope, the degree of elongation being also proportioned to the angle of the slope and therefore to the degree of ocular convergence. If for example, the figures are regular squares looked at from the direction of the diagonals, then they become greatly elongated rhombs.

Explanation.—Principles. If a slender rod *a b c* be held in a horizontal position in the median plane but a little below the horizontal plane passing through the two eyes, so that the eyes shall look down upon it at small angle, the perspective projection of the rod as seen by the two eyes will be according as we look at the farther end or the nearer end or the middle point.



In accordance with the mode of representation used in all my previous papers, capitals indicate objects or points seen single by binocular combination at the point of sight, small letters show right-eye-images and the same primed left-eye-images. In all cases, it is seen, the right and left-eye-images meet each other at the point of sight making *small angles.*

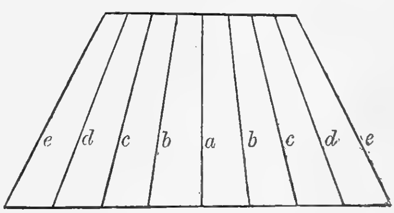
If, now, the rod instead of being held horizontally, be inclined by lifting the nearer end toward the plane of vision,* the angle of meeting or crossing of the two images becomes greater but the vertical length of the projection less, thus:



until, when the rod is *in* the plane of sight, the angle between the two images becomes 180° and the subtended vertical line of projection becomes 0°. In other words the projection becomes a continuous horizontal straight line. Of course, to the binocular observer it does not seem like a horizontal straight line, because he introduces the element of depth of space by *binocular* perspective. To him it will look like a v or an x looked at *end on.*

Application of principles.—The figures of a regularly tessellated plane must of course lie in parallel lines. We will suppose these parallels to run from the observer. By geometric or monocular perspective such lines on a horizontal floor converge to vanishing point on the horizon. Fig. 1 represents a projection of such parallels. This is as seen with *one eye.* As seen with two eyes there are, of course, two images of all these lines

1.



* The plane passing through the optic centers and the point of sight or through the two visual lines.

crossing each other at small angles as shown above. Let us fix our thoughts on the middle one only. In natural vision, the two images of this line *a* will cross one another at small angle at the point of sight as already explained. But in making the phantom-images the lines *bb* or *cc* or *dd* or *ee*, etc., are brought together in the middle and *viewed as the middle line.* But it is evident that the angle of perspective convergence and therefore the angle of crossing one another where they come together is greater and greater as they are brought from greater distances right and left. In other words: *the perspective angle is added to the binocular angle and all credited to the binocular angle because viewed as a middle line* which ought to have no perspective angle. But we have already seen that crossing of binocular images at greater angles means a nearer approach to the plane of sight—a looking more "*end on.*" In other words, it means in this case a lifting of the hither end of the plane. As more and more separated, figures *bb*, *cc*, *dd*, *ee*, etc., are successively brought forward and united in front, the angle of crossing of the lines and therefore the inclination of the phantom-plane becomes greater, until if we could bring together from infinite distance, the phantom plane would coincide with the plane of sight, i. e., would slope at an angle of 45°.

So much for the explanation of the inclination of the plane; now for that of the elongation of the figures.

As already seen, the projection—or what amounts to the same thing the retinal image—of a horizontal line in the median plane is shortened, or the vertical angle subtended at the eye is lessened in proportion as the line is brought nearer to the plane of sight by lifting the nearer end. Therefore, in order to subtend the *same* angle under these conditions it would require a *longer line.* Now in the phantom-image the subtending angle remains constant. Therefore in proportion as the phantom plane is apparently lifted toward the plane of sight, the plane and all its figures must appear to elongate in the direction of the slope. The elongation is greater in proportion as the phantom plane approaches the plane of sight and therefore without limit except the power of the eyes to combine more and more distant points right and left.

Experiment 2. In the case of the floor, the body of the observer prevents the viewing of the phantom in the other direction, i. e., by looking obliquely backward, unless indeed the observer could place himsef horizontally above the floor face downward. We therefore take next a vertical wall, such as a regularly figured wall papering of small pattern or a coarse wire-netting. The windows of the basement of one of the university buildings are protected by a coarse wire netting with lozenge-shaped meshes about 2½ inches in their shorter or horizontal diameter.

Standing before this and combining by extreme convergence, on looking obliquely upward the phantom plane slopes away from the observer; on looking obliquely downward it slopes away downward. So that sweeping the point of sight upward and downward alternately, the phantom plane dips away fore and aft from a transverse anticline forming a kind of arch. The explanation of this is of course the same as that already given for the floor.

It is important to state that this slope was seen only in looking obliquely upward or downward, *and not at all in looking steadily at right angles to the plane.* I said at right angles. In reality the neutral point is not exactly on a level with the eyes, but about 7° above. This is the result of the rotation of the eyes on the optic axes in convergence, as shown in one of my previous papers, and is a beautiful demonstration of such rotation.

Experiment 3.—We have thus far experimented only by looking obliquely upward or downward on the plane. If now we look directly at right angles (or in reality a trifle above the perpendicular) on the plane, whether floor, or vertical wall, or wire-screen, then, on extreme convergence, the phantom plane is seen to *slope away on each side*, so as to form a transverse arch. On sweeping the eyes upward and downward, the fore-and-aft sloping combined with the side ways sloping, gives the appearance of a mound sloping in all directions. But if the eyes are steady, only the transverse arching is seen. In fact, under these conditions I seem to see a fore and aft concavity, which, combined with the transverse arching, gives a saddle-shape surface.

Explanation.—Principles. All the phenomena of binocular vision, as already said, may be, and in last resort can only be, explained by the law of corresponding points. In the explanation of the phenomena described under experiments 1 and 2, it was only necessary to trace the cause back to the behavior of the double images of a rod viewed binocularly in various positions; but this behavior is itself explained only by the law of corresponding points. But the phenomena of the last experiment can best, perhaps only, be explained by direct reference to that law. It is necessary, however, to have a clear conception of the law in order to understand the explanation.

Corresponding points are points in the two retinæ exactly *similarly situated*, i. e. taking the central spot as pole, having the same latitude and longitude. Or to express it differently, if the two retinæ were laid one on the other so as to coincide in the manner of geometric figures, then the coincident points are corresponding points. Or again, the distance between all corresponding points is the same. If therefore we open a pair of di-

viders so that the points are exactly separated by that distance and then holding it *level* touch the two retinae any where, the points touched will be corresponding points. This distance is called the interocular base. It varies in different eyes; in my own it is exactly 62^{mm}. It is probable that the two retinæ thus correspond rod for rod and cone for cone. The central spots are par excellence corresponding points.

Now the law asserts that impressions on corresponding points are referred outward to the same point in space and therefore seen single, while impressions on non-corresponding points are referred outward to different points in space and therefore seen double. Furthermore—and this is the important point in the subsequent explanation—if the non-corresponding points impressed be *farther apart* than the distance between corresponding points or than the interocular base, then the double images are *heteronymous*, i. e. the left image belongs to the right eye and the right image to the left eye; but if the impressed points are *nearer together* than corresponding points, then the double images are *homonymous*, i. e. are on the same side as the eye to which they respectively belong. Now, in the former case, i. e. when the impressed points are too far apart, the impressing object is *nearer* than the point of sight; while in the latter case, i. e. when the impressed points are too near together, the impressing object is *further off* than the point of sight.

Application.—We are now prepared to explain the last experiment. In fig. 2, P P is a section of a tessellated plane, and *a*, *b*, *c*, represents the position of the regular figures; O O the optic centres or nodal points of the two eyes and R R portions of the two retinæ. The eyes are supposed to be fixed steadily

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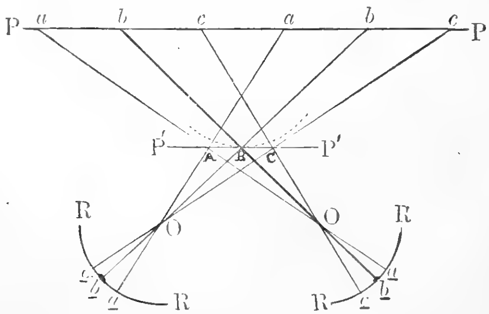


on *b b*, which therefore impress corresponding points, viz.: the central spots $\bar{b}\,\bar{b}$ and consequently are seen combined as one at the point of sight B. At the same time *a a* and *c c* also are supposed to combine and by geometrical construction would be

seen at A and C, and the phantom plane would be P′ P′. Such it would be by geometric construction and thus it is always represented. Such would indeed be the case of the retinæ were a *plane* parallel with P P. But the retinæ are spherical concaves, and for this reason when $\bar{b}\,\bar{b}$ fall on corresponding points, viz: the central spots $\bar{b}\,\bar{b}$, *a a* and *c c* do not fall on exactly corresponding points; for it is evident on inspection that the retinal points $\bar{a}\,\bar{a}$ and $\bar{c}\,\bar{c}$ *are nearer together than* $\bar{b}\,\bar{b}$. Therefore they form homonymously double images and are therefore referred to, and combined at, a point *farther away than* B. Therefore the phantom surface must appear curved from side to side, as shown in the dotted line.

Prof. LeConte Stevens, in an article published in 1882,* explains this phenomenon of transverse curvature of the phantom image by "changes in muscular tension," or as I would say, changes in axial adjustment. But (1) no such changes are necessary to perceive the phenomenon. The curvature is best seen with the point of sight fixed and is doubtless due to the slight (perhaps not consciously perceptible) homonymous doubling of the images of points right and left of the point of sight. And (2) in any case the fundamental explanation is found only in the law of corresponding points; for this law alone explains the necessity of the changes in axial adjustment, which are necessary to combine the double images. The true explanation is indeed involved in Prof. Stevens's figure (3) and especially in his statement that it is the result of the concavity of the retina; but he apparently does not see its necessary connection with the law of corresponding points, and even seems to doubt the validity of that law.†

Experiment 4.—Prof. Stevens‡ has devised a beautiful and ingenious method of bringing out strongly the transverse curvature of phantom images. But the curvature brought out by his method has largely a different cause from that already described, as we now proceed to show.

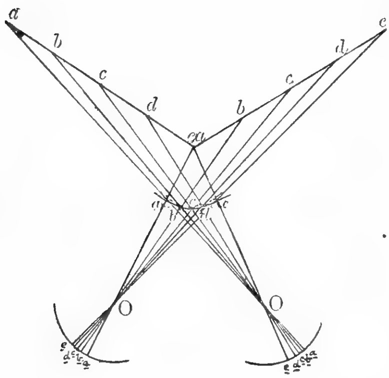
We have seen that the curvature in the preceding experiments is due to the extreme, but varying, obliquity of the parts combined. Now it is evident that this obliquity may be more easily gotten and the combination effected without extreme and straining convergence, by simply bending the plane at the middle line and inclining the two halves in opposite directions. This method has the additional advantage of allowing inclinations backward or forward and thus producing reverse effects; and also of allowing combination of the oblique surfaces beyond the plane of the object, either by naked eyes or by

* This Journal, vol. xxiii, p. 297 and seq. † Ibid., pp. 300 and 301.
‡ Ibid., p. 298.

the stereoscope, and thus also producing reverse effects. But it has also the great, the fatal disadvantage for our purposes, that the phenomena of curvature, as already explained, are complicated by a curvature developed even by geometric construction.

For example, figs. 3 and 4, represent cards with regular figures bent in the middle, backward in fig. 3 and forward in fig. 4. The reason of the stronger curvature is obvious on inspection of the figures.

3.



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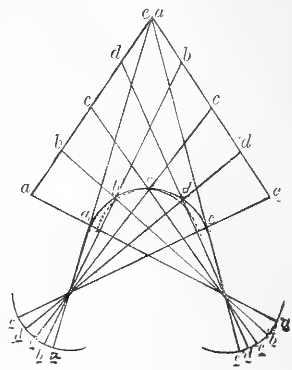


By geometric construction the phantom in fig. 3 is already convexly curved and by the law of corresponding points, as already explained, would be still more curved, as shown in the dotted line. Similarly in fig. 4 by geometric construction the phantom would be concave, and by the law of corresponding points still more concave, as shown in the dotted line. In this latter case inspection of the figure shows that with the point of sight at *c*, points right and left as *a*, *b*, *d*, *e*, of phantom, would fall on non-corresponding points of the two retinæ *aa*, *bb*, *dd*, *ee farther apart* than *cc*, and therefore the impressing object will seem *nearer* than the point of sight and nearer also than geometric construction would make it. This would increase the apparent curve. In other words, even with flat retinæ the phantom surface would in both cases be curved, but the curve of the retinæ in both cases exaggerates the curvature of the phantom.

It is needless to say, that in combination beyond the plane of the cards, whether by naked eyes or by stereoscope, the phenomena would be exactly the same, only reversed, i. e. in fig. 3, it would be concave and fig. 4 convex.

Another phenomenon I have observed in these last experiments of cross combination. In fig. 3 the phantom is not only convex from side to side, but concave fore and aft, i. e. it is

distinctly saddle-shaped. It will be also remembered that the same fore and aft curvature was observed in experiment 3. In fig. 4, the phantom is not only concave from side to side, but convex fore and aft. The explanation of this fore and aft curvature I am not yet able to give.

The concavity and convexity of concentric circles, drawn on two planes inclined toward, or away from each other and viewed by binocular combination—one of the most beautiful phenomena brought out by Prof. Stevens—must be explained, partly at least in a different way. This has been done very perfectly by him. We only mention it to avoid confusion. Figures of other forms do not appear curved in two directions *alike*, as concentric circles do, but on the contrary, often as already said, in *opposite directions.*

Some general remarks suggested by the above.

(1.) I believe, indeed am quite sure, that the phenomenon of transverse curvature of the phantom surfaces described above is a necessary result of the "*horopteric circle of Müller;*" for this circle is the necessary consequence of the concavity of the retina together with the law of corresponding points.

Supposing, for the moment, that the eyes in convergence moved on vertical axes, i. e., without rotation on the optic axis,* then it may be shown that with the point of sight fixed, other objects right and left of that point, in order that their retinal images should fall on corresponding points, must lie, not in a plane, but in a circle passing through the point of sight and the nodal points. This is called the horopteric circle of Müller. The images of objects or points on a *plane* passing through the point of sight would not fall on corresponding points but on points nearer together than such points, and therefore a plane surface ought to appear convex, like the surface of a cylinder with reverse curvature equal to that of the horopteric circle. We do not ordinarily observe this because in planes at the usual distance the curvature is too small to be detected near the point of sight, and at a distance from that point, right or left, vision is too indistinct for accurate observation. The form of any surface is practically always gotten by sweeping the point of sight over the surface and gathering up the result in memory, the distance of that point being always truly estimated. But in the case of phantom images in proportion as the point of sight comes nearer, the curvature (by definition of horopteric circle) becomes greater until it becomes quite distinct.

Now if a plane is seen as a horopteric curve reversed, it is evident that a horopteric curve ought to be seen as a plane, and

*This is not exactly true, especially in strong convergence. This Jour., vol xlvii, p. 153, 1869.

this would be most distinct, in fact would be perceivable only in the case of phantom images. If, therefore, we had a circular room with regular tessellated wall, and leaning with back against one side we combined the figures by extreme convergence, I suppose the phantom image would appear plane. It would be interesting to verify this prevision by experiment.

(2.) I have said that all the phenomena of binocular vision are explained by the law of corresponding points. In my previous papers* I have contended that the perception of binocular perspective of *different* objects, one beyond the other, and of binocular relief of the *same* object, is due not only to the perception of double images, but of these as homonymous and heteronymous, the one as belonging to objects or points beyond, the other to those nearer than, the point of sight. It has been objected to this view, that in many cases we distinctly perceive relief without being able to detect double images of any kind either homonymous or heteronymous. This objection, it seems to me, shows a misconception. It is well known that most persons are at first wholly unconscious of double images, even though they constantly base their visual judgments on them. Then, when their attention is called to them, they learn to perceive them *consciously* if they are very distinct and far apart. Then, in proportion to careful attention, those persons most practiced in binocular experiments see them in cases where they are less and less separated. But in all persons, even the most practiced, there is still a residuum, decreasing with practice, of unperceived or unconsciously perceived double images, upon which judgments of relative distance are based. But is it not rational to place these residual cases also in the same category with those we have already learned to distinguish; and to say that subtle *unconscious perceptions of double images* is the mode by which we judge of relief in these cases also? Or we may leave out of view the question of double external images and refer only to the law of corresponding points. I would then give the theory of binocular relief as follows: Impressions on corresponding points are referred to objects at the point of sight or at that distance; but impressions on non-corresponding points—even though it be but the next contiguous rod right or left—are referred to distances greater or less than the point of sight; if the impressed points are farther apart than corresponding points the impression is referred to distances *nearer*, if the impressed points are nearer together than corresponding points to distances *farther* than the point of sight. This is an inherited capacity which may be partly or even largely, but not wholly, analyzed into its effects as double images.

* This Jour., III, vol. ii, p. 1, 1871, and same vol. ii, p. 417.

This capacity is not unique, except in its extreme refinement. The same is true of all bodily actions and sense-perceptions. For example, the complex and delicate play of muscular action in maintaining equilibrium in standing, the subtle causes or signs of facial expression, often elude our utmost power of analysis. Under the same head also comes the so-called *muscle-reading*, only that this is possible in but few while *face-reading* is practiced by all. In all such cases we are guided or judge by subtle signs which escape conscious detection; but we would be wrong to conclude on that account that the signs are not physical.

(3.) Geometric construction in the manner of Brewster is useful or even indispensable in representing binocular visual phenomena, because it is simple and easily understood. But as soon as we study carefully we find that this method does not give truly the place of double images. (1) In the representation of binocular perspective of objects or points one beyond the other it utterly fails, because when it tries to represent the double images it does not represent the relative distance; and when it tries to represent the relative distances it does not represent the doubling of the images. It was to remedy this defect that I proposed and put in practice a "new method of diagrammatic representation."* This new method represents truly all the phenomena of binocular perspective of objects lying one beyond another *in the line of sight*, but cannot represent objects or points on a phantom plane. (2) In the phantom image of a tessellated plane, a case for which it seems eminently adapted, the ordinary geometric construction, as we have seen, cannot truly represent the form of the surface on account of the concavity of the retina. The law of corresponding points, however, completely explains it. (3) In the case of *ocular divergence*, all diagrammatic representations of distance of course fail, for in this case there is no point of optic convergence, and therefore no point of sight. But even these cases are easily reducible to the law of corresponding points. I drew attention to and explained these cases in 1875.*

We repeat then that the law of corresponding points is by far the most fundamental and general law of binocular vision. But it is not necessary, in order to explain the oneness of the impressions on corresponding rods or cones, to assume, as some do, that these are two nerve-fiber-terminals of *one* brain cell. This wonderful property is probably *an acquired* one; not indeed acquired by individual experience alone, but by the experience of the whole line of vertebrate ancestry inherited and accumulated. Its wonderful, almost mathematical exactness is the result of the exquisite refinement of retinal structure and the constant use of the eye in the accurate estimate of distance.

*This Jour., vol. ix, p. 163, 1875

ART. XIII.—*Crocidolite from Cumberland, R. I., with a discussion of the composition of this and allied minerals, and a method for the determination of ferrous oxide in insoluble silicates;* by ALBERT H. CHESTER, and F. I. CAIRNS.

1. *Crocidolite.*

THE occurrence of crocidolite in Rhode Island was announced some years ago by one of the writers,* but nothing more than to establish its identity was done at that time. Our recent work has been undertaken not only to make a thorough analysis of the mineral from this locality, but also to throw some light, if possible, on the constitution of the species. It occurs at Beacon Pole Hill, close to the well known mineral locality, Diamond Hill, Cumberland, R. I., in seams in a granite ledge. It is usually disseminated in fine particles through feldspar, but often occurs in larger masses, up to the size of a butternut. Unbroken surfaces sometimes present a botryoidal appearance, and the nodules when broken show a radiated structure like wavellite, but much less marked; indeed in these specimens the fibrous structure is not always very apparent to the eye, though readily seen by the aid of a magnifier. The fibers are short, very fine, and interlaced or matted together in an irregular manner, except where the radiated forms are seen. Its color is usually a dark bluish gray, the radiated nodules, however, being darker, almost an indigo-blue, while the streak has a slightly lighter shade of the same gray. It is associated with dolomite, glassy quartz, and rarely with light purple fluorite. The feldspar matrix is grayish white in color, except where stained with iron, and coarsely granular, though occasionally small cleavage planes may be seen. It is judged to be albite from its easy fusibility, and from the intense yellow color it gives to the blowpipe flame.

One of the larger masses afforded a sample for analysis wholly free from gangue, as proved by careful examination with the magnifier, as well as from the absence of all gritty particles when pulverized in the agate mortar. It easily breaks down under the pestle into a mass, which, though soft and feeling perfectly smooth, is so tough as to require long and hard rubbing to make it sufficiently fine for analysis.

Tested qualitatively it was found to consist of silica, oxide of iron, soda, water, and a little magnesia. Before the blowpipe it gives the usual reactions of crocidolite, including the alkaline water when heated in a closed tube. Its specific gravity is 3·2. No hygroscopic water was given off when

* Dana's Man. of Min. and Lith., third edition, p. 252, 1879.

the sample, powdered for analysis, was kept for two hours at a temperature of 110° C.

In executing the following analyses the water was determined by direct weight, the pulverized mineral being heated to faint redness in a glass tube and the water collected in a weighed chloride of calcium tube. The ferrous oxide was determined by the ammonium fluoride method given beyond, the soda by heating with calcium carbonate and ammonium chloride, and the other constituents by fusion with sodium carbonate in the usual manner. To corroborate the determination of ferrous oxide a calculation was made from the difference between the weight of the water found and the actual loss sustained by the sample, this difference presumably representing the amount of oxygen required to convert the ferrous oxide into ferric. The average of four water determinations is 3·56 per cent, while the average loss by heat was 1·03 per cent. The difference, 2·53 per cent, represents oxygen, and corresponds to 22·77 per cent of ferrous oxide, corroborating the results obtained by the other method, which are the figures used in the following analyses.

	1.	2.
SiO_2	52·13	51·03
Fe_2O_3	15·93	17·88
FeO	21·25	21·19
MgO	0·22	0·09
Na_2O	6·26	6·41
H_2O	3·95	3·64
Total	99·74	99·94

There seem to be good grounds for considering the water basic, and an essential constituent, for it requires nearly, if not quite, a red heat to drive it all out, and the taking up of oxygen at the same time shows a molecular rearrangement. Under the supposition that the water is basic the empyrical formula suggested is $Fe_3Na_2H_4Fe_2Si_9O_{27}$, or 3FeO, Na_2O, $2H_2O$, Fe_2O_3, $9SiO_2$, which requires the percentages given in the first column of the table below, the second column giving the ratio calculated from the same figures by dividing the percentages of the oxides found by their molecular weights, and the third column the ratio calculated from the average of the two analyses given above.

	1.	1.	3.
SiO_2	53·25	·887	·860
Fe_2O_3	15·78	·098	·105
FeO	21·31	·296	·299*
Na_2O	6·11	·098	·102
H_2O	3·55	·197	·210

* With the MgO.

The mineral comes, then, under the general formula, $R_6RSi_9O_{27}$, where $RO=FeO:Na_2O:H_2O:=3:1:2$, and seems fairly entitled to take rank as one of the well authenticated mineral species.

Let us now compare the figures given above with the published analyses of this mineral, which have all been made on the crocidolite from South Africa, with the exception of one by Delesse, to be considered later.

Analyses.

	1*	2†	3‡
SiO_2	50·81	51·64	52·11
Fe_2O_3			20·62
Al_2O_3			1·01
FeO	33·88	34·38	16·75
MgO	2·32	2·64	1·77
CaO	0·02	0·05	
Na_2O	7·03	7·11	[6·16]
Mn_2O_3	0·17	0·02	
H_2O	5·58	4·11	1·58

In analyses 1 and 2 no attempt was made to determine the ferrous oxide, and in 3 it it was determined by the hydrofluoric acid process in presence of carbon dioxide, a method that will only give accurate results if care is taken not to raise the heat too high. The total amount of iron found in each analysis calculated to Fe_2O_3 is as follows:

	1.	2.	3.
Fe_2O_3	37·65	38·20	39·23

while in the mineral from Rhode Island it is 40·46 per cent.

If now we correct these analyses to correspond with our formula, calculating ferrous oxide in proportion to the silica found in each case we shall have

	1.	2.	3.
SiO_2	50·81	51·64	52·11
Fe_2O_3	18·60	19·46	18·49
Al_2O_3			1·01
FeO	17·16	16·84	18·74
MgO	2·32	2·64	1·77
Na_2O	7·03	7·11	[6·16]
H_2O	5·88	4·11	1·58

The ratios calculated from these revised figures are as follows:

* Stromeyer, fibrous var., Gött. gel. Anz., p. 1585, 1831.
† Stromeyer, earthy var., Gött. gel. Anz., p. 1585, 1831.
‡ Dölter, Zeitschr. Kryst.. iv, 40, 1879.

	1.		2.		3.
SiO_2	·847		·861		·869
Fe_2O_3	·116		·122	·115	·125
Al_2O_3				·010	
FeO	·239	·296	·237	·303	·260	·304
MgO	·057		·066		·044	
Na_2O	·113		·115		·099
H_2O	·310		·228		·088

showing as close an agreement among themselves and with the figures before given as could be expected between analyses made by different persons, using different methods, and on specimens from different localities. The ferric oxide is high according to these figures, and still higher in 3, if we use those originally given by Dölter for his analysis; but this is easily explained if one examines a specimen of the "Cape" crocidolite, the fibers of which are seen to be more or less coated with ferric hydrate, so that it would be difficult, if not impossible, to select an absolutely pure sample for analysis. The mineral from Rhode Island seems to be of purer material, and hence better fitted for an examination on the results of which a formula is to be calculated.

2. *Abriachanite.*

Heddle* has given the following analysis for a mineral which he named *Abriachanite;* the 2d column showing the calculated ratios:

Abriachanite.	1.	2.		*Vosges Crocidolite.*	1.	2.	
SiO_2	51·15		·853	SiO_2	53·02		·888
Fe_2O_3	14·92		·090	Fe_2O_3	15·95		·099
FeO	9·80	·136		FeO	11·29	·157	
MgO	10·80	·270	·426	MgO	10·14	·254	·430
CaO	1·12	·020		CaO	1·10	·019	
Na_2O	6·52	·105	·112	Na_2O	5·69	·092	·096
K_2O	0·63	·007		K_2O	0·39	·004	
H_2O	3·82		·212	H_2O	2·52		·140
Moisture	·95						
Total	99·71						

Here we have the ratio $SiO_2 : Fe_2O_3 : FeO : MgO : Na_2O : H_2O = 9 : 1 : 4 : 1 : 2$, where $MgO : FeO = 2 : 1$. If now we correct the analysis of crocidolite from the Vosges Mountains given by Delesse† so as to make the proportions of ferrous and ferric oxide agree with these ratios, we obtain results as above.

* Min. Mag., iii, 61, 1879.

† Ann. des Mines, III, x, 317, 1836.

A comparison of these figures with those given for abriachanite forces us to the conclusion that the two analyses are made on essentially the same substance, and that Heddle's mineral is simply a magnesian variety of crocidolite. The name abriachanite, if retained at all, may be kept as the name of this variety.

In this connection it is proper to notice the crocidolite-like mineral from Mexico described by Bauer,* and referred by him to asbestos. The table below gives his analysis and the calculated ratios.

	1.		
SiO_2	55·48		·925
Fe_2O_3	12·32	·077	·096
Al_2O_3	2·01	·019	
CaO	10·35	·185	·723
MgO	17·23	·431	
Na_2O	1·54	·025	
H_2O	1·47	·082	

Here, although lime has taken the place of ferrous oxide, and there is much less soda and water, yet the ratio of $SiO_2 : R_2O_3 : RO$ is practically the same as in the last-named variety. It also agrees with crocidolite in its physical and pyrognostic characters. It stands then as a connecting link between crocidolite and amphibole, and perhaps indicates the true relations of the former mineral. We certainly cannot agree with the conclusions of Dölter,† afterward sustained by Kenngott,‡ who considers crocidolite merely a fibrous variety of arfvedsonite, for to carry out this idea, Kenngott is obliged to throw the water out of consideration as non-essential, and to make no account of about five per cent of the silica in Stromeyer's analyses, and of nearly seven per cent in Dölter's, which, as he says himself, "is difficult to explain." And the true nature of arfvedsonite can hardly be considered as settled, for Lorenzen's recent analysis,§ with the formula deduced from it, is so totally different from any before it as to render its further examination quite necessary.

In looking over the figures of the various analyses quoted above, the widest variation is noticed in those given for water, varying from 1·58 to 5·58. Supposing the analyses all to be made on essentially the same mineral this may result from either of two causes. In the first place, where it is high, part of it may be non-essential, as is the case in Heddle's analysis, where 0·95 per cent went off at 100°, leaving 3·82 as that actually belonging to the mineral. Then, where the result is low it may have been determined by the loss when heated. Such a determination will always be too low on this mineral, for at the

* Z. f. Kryst., iv, 40, 1879.

† Neu. Jahrb. f. Min., iii, p. 163, 1885.

‡ Min. Mag., v, 50, 1882.

§ Neu. Jahrb. Min., i, p. 158, 1882.

temperature required to drive off the water some, if not all, of the ferrous oxide will take up oxygen, the amount taken up depending on the time and the temperature to which it is heated.

3. *Determination of Ferrous Oxide.*

The determination of ferrous oxide in insoluble silicates by the use of hydrofluoric acid in the presence of carbon dioxide presents so many difficulties that in many cases it has not been attempted, although essential to a proper understanding of the constitution of the mineral under consideration. In 1867, Prof. Cooke described* a method which gives excellent results, and which requires the use of only simple apparatus, the principal objection to it being the difficulty of obtaining pure concentrated hydrofluoric acid. In 1877, Prof. Leeds, at a meeting of the New York Academy of Science, read a paper† on a new method, where the hydrofluoric acid used is manufactured during the progress of the analysis, within the apparatus employed. Very good results are also obtained by this method, but the apparatus is somewhat complicated. A third method is given by Dölter‡ which seems to be quite satisfactory, but here again hydrofluoric acid is employed.

We have used ammonium fluoride, a substance which can readily be obtained pure, and can be kept unchanged. The method is in short as follows: About 0·5 gm. of the pulverized mineral is put into a large platinum crucible over a water bath, and a slow stream of carbon dioxide is carried into it. When the air is expelled, a few drops of concentrated sulphuric acid are added, then some pure ammonium fluoride and the whole stirred with a platinum spatula. Similar additions are made from time to time, until the mineral is completely decomposed, when the contents of the crucible are emptied in a beaker containing cold water, the solution diluted, and the iron determined as usual by means of potassium permanganate.

There are several points with reference to apparatus and manipulation that it is desirable to describe more in detail.

Fine pulverization of the mineral is quite necessary, and we have found it desirable to rub the powder a second time in the agate mortar, after the sample had received the usual preparation for decomposition by fusion.

The platinum crucible should be of at least 50 c.c. capacity so that it can be immersed in the hot water of the water bath to the height that the frothing reaches inside at the beginning of the operation. Otherwise some of the material carried up by the froth may stick to the sides of the crucible, and not be thoroughly decomposed.

* This Journal, II, xliv, p. 347, 1867. † Am. Chemist, vii, p. 396, 1877.
‡ Zeitschr. f. Anal. Chem., xviii, 50, 1879.

The crucible may be conveniently covered by two pieces of platinum foil, lapping a little at the middle, and with the corners bent down over its edges to keep them in place. A hole through one of them admits the end of the tube conveying carbon dioxide. The other covering piece, lapping over the first, has one corner cut away a little to admit a small platinum spatula, or stiff wire, which remains in the crucible during the whole operation.

A bent tube of hard glass, enlarged a little near the end, which passes through the hole to prevent it from slipping in too far, conveys the carbon dioxide from a generator, or more conveniently, from a gasometer, to the crucible. Between the gasometer and the crucible a washing bottle charged with concentrated sulphuric acid should be placed.

The pulverized mineral is put into the crucible on the water bath, which should be kept boiling during the whole operation, the carbonic acid turned on and allowed to drive the air out. The flow may then be reduced to about two bubbles per second, which is quite sufficient to keep the crucible filled with the gas. A few cubic cent. of concentrated sulphuric acid are then stirred up with the powder, and finally a little ammonium fluoride is added, causing a violent frothing of the materials. After this action has ceased more of the reagents are added in several portions until such an addition causes no apparent change. The operation requires about 25 mg. of the fluoride for every 10 mg. of silica in the sample; that is, for 0 5 gm. of a silicate containing about 50 per cent of silica 1·25 gm. of fluoride will be needed, added in three or four portions, at intervals of five to ten minutes, sufficient sulphuric acid being added with it to keep the mass fluid. It is desirable to stir it up frequently, particularly during the first part of the process, and for this reason, as well as for convenience in watching the operation, the cover is made in two pieces, so that one can be readily removed and replaced.

Decomposition being complete, the contents of the crucible may be poured into a large beaker containing cold water, the crucible and spatula washed into it, the solution properly diluted and titrated as usual. In cases where the mineral contains much ferric silicate, a basic salt, insoluble in cold water, will be formed. If desired, the beaker may be filled with carbon dioxide, and the contents heated until a perfectly clear solution is obtained, but this is not necessary, for all the ferrous sulphate dissolves in the cold water, and the milkiness produced by the other does not interfere in the least with the delicacy of the color reaction, but rather aids it.

Several experiments were made to test the accuracy of this method with results given below. Two sources of inaccuracy

are possible; first, that oxidation should take place; second, that the mineral should not be perfectly decomposed. To settle the first point two soluble silicates, and a sample of dunyte from North Carolina, and the other a rolling mill cinder, were treated by our process, and afterwards by decomposition with sulphuric acid in a flask, in an atmosphere of carbon dioxide, with results as follows:

	1.	2.
Dunite	2·72	2·72
Cinder	59·60	59·88

Showing closely accordant results. To settle the question as to complete decomposition duplicate determinations were made on pyroxene from Vesuvius, and on the crocidolite from Cumberland, R. I.

	1.	2.
Pyroxene	4·59	4·59
Crocidolite	21·19	21·25

That the decomposition is complete and the results obtained are to be relied on, is proved not only by the agreement shown above, but also by the absence of all gritty particles in the beaker after solution, and by the fact that complete solution takes place on heating, or even after a few hours standing in the cold, after titration.

The whole operation requires about one hour from the time the mineral is put into the crucible to the final determination of the iron. The time required for pulverization cannot be lessened, however, for unless this part of the work is carefully done, decomposition will not be complete. In several experiments on the cinder named above the loss was found to be from three to six per cent of the ferrous oxide known to be contained in it, and it was at first feared that the method would prove a failure on certain silicates; but finer pulverization completely overcame the difficulty and there was afterwards no trouble with any of the silicates on which we experimented.

Hamilton College, March 29th, 1887.

NOTE.—Since writing the above the attention of the authors has been called to an article by C. E. Avery* entitled "Decomposition of refractory Silicates by Fluorides." In this article the use of a metallic fluoride is proposed for the purpose mentioned, but no suggestion is made as to ferrous oxide, nor are any details of the process given. In Crooke's "Select Methods of Chemical Analysis"† the application of this method to the determination of ferrous oxide is suggested, but here only meagre details are given and in both cases objection is made to the use of ammonium fluoride, which we have found most convenient and satisfactory.

* Chemical News, vol. xix, p. 270, 1869. † Edition of 1886, p. 133.

We have also been so fortunate as to secure a sample of the crocidolite from Orange River, South Africa, and have analyzed it with the following results:

		Ratio.	
SiO_2	52·11		·869
FeO	16·51	·229	
CaO	0·75	·022	·298
MgO	1·88	·047	
Na_2O	5·79		·093
H_2O	3·53		·196
Fe_2O_3	20·26		1·26
Total	100·83		

This will be seen to agree very well with the formula suggested for the Rhode Island crocidolite, except that there is an excess of ferric oxide, amounting to about four per cent. This result is to be expected, for the sample contained this oxide of iron in visible form, coating the fibers with a brown crust, and so closely adhering to them, as to make it quite impossible to obtain a sample for analysis free from this impurity, though every pains was taken to do so.

Art. XIV.—*Chemical Integration;* by T. Sterry Hunt.

[Read before the National Academy of Sciences at Washington, April 19, 1887.]

§ 1. The process of chemical union or combination has been defined as interpenetration and as identification, by Kant and by Hegel, and more recently, by the present writer, as integration; all changes in matter, as Herbert Spencer has well said, being resolvable into integration and disintegration. This process may take place either among unlike or like species, being in the latter case a homogeneous integration, constituting what is called polymerization; while depolymerization is a homogeneous disintegration. These two forms of the chemical process, as was defined in 1853, are respectively metamorphoses by condensation and by expansion, and were by the writer then included under the name of *chemical metamorphosis.* The relations of these homogeneous changes to heterogeneous integration and heterogeneous disintegration, which give rise to species differing in centesimal composition from the parents, and constitute what was at the same time distinguished as *chemical metagenesis*—are obvious.

§ 2. It was further shown that heterogeneous integration followed by heterogeneous disintegration or dissociation, giving rise to two species unlike the parents, constitutes what is called double decomposition, and that a similar heterogeneous integration, followed by a homogeneous dissociation, is seen when chlorine and hydrogen gases by their union give rise to chlor-

hydric gas, without change of volume; the condensation involved in the process of integration being immediately followed by an expansion of similar amount. The law of chemical condensation and chemical expansion being universal, there is theoretically no limit to either of these processes. Such homogeneous expansion or dissociation, it is known, takes place in elemental gaseous species, as when the vapors of sulphur and iodine are exposed to elevated temperatures, as well as in the vapors of compound species like nitric peroxyd, acetic acid and turpentine-oil.

§ 3. The chemical species, to those agencies which do not effect its disintegration, is a complete entity or integer. This, in the case of homogeneous integration in gases and vapors, is generated by the condensation into a single volume of two or more volumes of a less dense species. The designation of polymers given to such condensed species, implying that they are made up of many parts, carries with it the notion of building by additions, and thus of complexity rather than of integrity; it is therefore rejected.

We assume hydrogen as the type of the normal integer, and the weight of two portions of this element ($H_2=2·0$) being the unit, the weight of a like volume of any other gas or vapor is its equivalent weight; that is to say, the weight of a volume equal to H_2. This, in the language of the atomic hypothesis, is its molecular weight; the so-called atomic weights being the smallest combining weights of the elemental species, compared with $H=1·0$.

§ 4. The normal integers of oxygen, hydrogen and chlorine, and of bromine and iodine vapors, are thus double or dyad integers, while ozone and the vapor of selenium below 800° are triple or triad, and that of sulphur vapor below 550°, is sextuple or hexad; all of these however at higher temperatures assuming the densities of the normal or dyad integers. The quadruple integers of phosphorus and arsenic vapors, there is reason to believe, undergo a like change; while the double integer of iodine at about 1500° becomes, as is well known, a single or monad integer, a result which at the highest temperatures of experiment, is already partially attained for bromine and chlorine; the vapors of mercury and cadmium being known to us only in this condition of monad integers. Such a state, from analogy, we may conceive would be attained under favorable conditions of temperature and pressure for the vapors of all known elements, and may, as the writer has elsewhere suggested, actually take place, for many species, in the electric arc; while, as he was the first to point out, in 1867, a still further dissociation, yielding unknown and still more elemental forms, probably appears in solar and nebulous matter.

The subject of homogeneous disintegration by heat is further illustrated by the vapor of nitric peroxyd, of acetic acid, of paraldehyde and of turpentine-oil. These integers of varying densities, and of varying equivalent weights, alike of so-called elements and of compounds having a similar centesimal composition may be conveniently designated higher and lower integers; the terms implying at the same time higher and lower specific gravities, and higher and lower equivalent or integral weights, since the density or specific gravity—as is well known, varies as the equivalent weight in the case of gases and vapors.

§ 5. A similar direct relation between equivalent weight and specific gravity in liquids and in solids was first indicated by the writer in 1848, and was again urged in 1853.* It was further insisted upon in a communication to the French Academy of Sciences in 1855, where after saying that "since the chemical combination of two bodies is to be regarded as an interpenetration of masses, and not as a juxtaposition of molecules, the atomic hypothesis is not necessary for the explanation of the law of equivalent weights," it was added: "Their densities thus furnish us a means of fixing the equivalent weights of gases, and of bodies which volatilize without decomposition, and it remains to be determined if some law as simple as that of Gay-Lussac would not permit us to fix by similar means the equivalents of solids and non-volatile bodies."† The further development of this problem in subsequent years we have discussed at length in the volume cited above.

§ 6. In accordance with this conception the writer, in 1853, spoke of "that mode of metamorphosis which constitutes polymerism." The conception of polymerism or homogeneous integration as of universal application in chemistry was further insisted upon in 1867, when it was asserted that "the gas or vapor of a volatile body constitutes a species distinct from the same body in its liquid or solid state, the chemical formula of the latter being some multiple of the first; and the liquid and solid species often [probably always] constitute two distinct species of different equivalent weights." It was at the same time further asserted of the liquid and solid alcohols, acids,

* See the author's lately published volume. *A New Basis for Chemistry*, pp. 11, 12 and 38, 39, wherein the citations given below in this paragraph were, by inadvertence, omitted.

† Sur les Volumes Atomiques, Comptes Rendus de l'Académie des Sciences, xli, 77–81. "Puisque la combinaison chimique de deux corps doit être regardée comme une interpénétration des masses et non pas une juxtaposition des molécules, l'hypothèse atomique n'est pas nécéssaire pour expliquer la loi des poids équivalents." "Les densités nous fournissent ainsi un moyen de fixer les poids équivalents des gas et des corps qui sont vaporizables sans decomposition, et il restait à detérminer si quelque loi aussi simple que celle de Gay Lussac ne nous permettrait pas de fixer par un moyen semblable les équivalents des corps solids et non volatiles."

ethers and glycerids, that "these non-gaseous species are generated by the chemical union or identification [integration] of a number of volumes or equivalents of the gaseous species; which number varies inversely as the density of the species."* From this it follows that all condensation of gases and vapors by cold or pressure, and all fusion, solidification, and vaporization are chemical metamorphoses. The law of volumes, hitherto applied only to gases and vapors, extends to all solid and liquid species, and is a universal law.

§ 7. The identification of the processes of vaporization and condensation of vapors with chemical change is in accordance with the views enunciated by Henri Sainte-Claire Deville in his researches on dissociation between 1857 and 1865.† These views are well resumed in his final statement, in 1873,—that Isambert in his studies of the compounds of ammonia with chlorids "not only demonstrates the analogy between the phenomena of dissociation and of vaporization, but establishes their complete parallelism." Hence, in the opinion of Deville: "There is, according to these ideas, no essential difference between physical phenomena and chemical phenomena, or rather the passage from the one to the other is continuous."‡ It may be said in comment upon this remarkable statement that until the true nature of the processes of volatilization and vaporous condensation had been established those chemical phenomena marked by changes of state had been wrongly regarded as physical (or dynamical) phenomena. By "change of state" are here meant all changes between the conditions of gas, liquid and solid, as also the transformations of these, which are always marked by alterations in density, as well as in other physical characters. Illustrations of these changes are familiar alike in simple and in compound species.§

§ 8. It follows from these considerations that if the law of volumes, recognized by Gay-Lussac in the changes of gases and

* American Journal of Science, xliii, 205; also the writer's Chemical Geological Essays, 456, and A New Basis for Chemistry, 41, 42.

† A New Basis for Chemistry, 133–137.

‡ Report by Deville on a memoir by Troost and Hautefeuille, Sur les transformations isomériques et allotropiques; Comptes Rendus de l'Académie des Sciences, (1873) lxxvi. "Isambert . . . . non seulement demontre l'analogie entre les phenomènes de dissociation et de vaporization, mais en établit le parallelisme complet." . . . . . Il n'y a aucune différence, d'après ces idées, entre les phenomènes physiques et les phenomènes chimiques, ou plutôt le passage des uns aux autres se fait par des variations continues." Deville, *loco citato*.

§ Of phosphorus, which affords perhaps the most instructive example of these changes, there are known (1) The vaporous species. which according to Victor Meyer gives indication of conversion into a more elemental species at very high temperatures; (2) liquid phosphorus which boils at about 279°,—when it has a density of 1·5285—and may, under proper condition, be cooled to 20° or even to 0°, but below 44° is readily changed, with rise of temperature, into the solid transparent, colorless crystalline species, (3) which is luminous in the air, soluble, poisonous, a non-conductor of electricity, having at 40° a density of 1·806. This is converted by sun-light, by the action of iodine, by a temperature of 230°, or

vapors, is to be extended, as we have maintained, to their condensation into liquids and solids, so that for these, as for gases, the specific gravity is a function of the equivalent weight, we are forced to the conclusion that the equivalent or integral weights of liquids and solids are much more elevated than has been hitherto supposed. This the writer taught from 1853 up to 1885, although he had not in those years arrived at the simple means of fixing the value of these weights, subsequently set forth in 1886.*

These elevated equivalent weights furnish illustrations of the great principle of progressive series in chemistry, which, first recognized in 1842, by James Schiel, in the formula of related bodies differing by $n(CH_2)$, and in that form adopted by Charles Gerhardt in 1844, was in 1853 generalized by the present writer, and regarded as a principle of universal application. As then pointed out, progressive series in chemistry may be included under two heads: those in which the first term is the same as the common difference, as seen in polymerization or homogeneous integration, and those in which it is unlike the common difference. It was at that time asserted that there are progressive series,—having homologous relations between their members—differing not only by $n(CH_2)$, but by $n(OH_2)$, by $n(OM)$, and by $n(SM)$, as well as by $n(CMO_3)$.

The subject was further pursued in a communication to the French Academy of Sciences in 1855, when it was said, "These homologous relations, far from being limited to carbon compounds, are but examples of that numeric harmony seen by Laurent, and recognized by Dumas in the equivalents of the elements, which will become for chemistry a principle as wide in its application as those of atomic weights and volumes." Of the writer's studies of the latter, it was further said by him in 1855, that they were undertaken "in the hope of giving to mineral chemistry something of that exactitude which organic chemistry already possesses."†

more rapidly, with evolution of heat from the condensation, when exposed to the temperature of boiling sulphur [450°] into (4) the amorphous red species, insoluble, non-luminous, and non-poisonous, with a density of about 2·10. This species volatilizes in vacuo, without fusion, at 550° and is re-deposited in red crystals, which are perhaps identical with the red crystallized metalloidal species (5) got by melting lead with phosphorus under pressure, which has a density of 2·34 at 15°, and is a conductor of electricity. The forms of red phosphorus with intermediate densities are possibly mixtures of the last two species.

* See A New Basis for Chemistry, 100, 111.

† Comptes Rendus de l'Acad. des Sciences, xli. 77-81; sur les volumes atomiques. "Ces rapports d'homologie, loin d'être limités aux composés de carbone, ne sont que des examples de cette harmonie numérique que voyait déjà Laurent, que Dumas a reconnue dans les équivalents des eléments, et qui deviendrait pour la chimie un principe d'une application aussi large que ceux des poids et des volumes atomiques." "Dans l'espoir de donner à la chimie minérale quelque chose de cette exactitude que possède déjà la chimie organique." *Loco citato.*

§ 9. In a later note, on the Relation between certain Bodies differing by H_2 and O_2, presented to the same Academy in 1855, after recalling the above conclusions as to homologous series, it was maintained that similar relations may exist between bodies differing in their proportions of oxygen or of hydrogen. In support of this thesis, as regards oxygen, were then compared alike chemically and crystallographically, malic and tartaric acids, chlorates and perchlorates, sulphates, carbonates and sulphato carbonates. As regards hydrogen, the compound ammonias, $NH_3+n(CH_2)$, were compared with the analogous base piperidine, belonging to a series $NH+n(CH_2)$, and with arsine or methyl arsenid, $AsH+CH_2$. These facts, and other considerations, it was then argued, "lead us to admit an intimate relation between bodies differing by H_2" as well as by O_2 $(O = 8)$.*

§ 10. A further illustration of this extension of the conception of progressive series was soon afterwards afforded by the studies of J. P. Cooke on the crystallized alloys of zinc and antimony, which, with similar crystalline forms, present considerable variations in the proportions of their constituents, leading him to the conclusion that "zinc and antimony are capable of uniting in other proportions than those of their chemical equivalents, or, in other words, that the law of definite proportions is not so absolute as has been hitherto supposed."† In commenting on these results, as they had been set forth by Cooke in 1860, it was said by the writer in 1874: "These alloys of varying composition are to be regarded in part as examples of a progressive series of isomorphous compounds of antimony and zinc, of high equivalent, differing from each other nZn_3—and in part doubtless as crystalline mixtures of these isomorphous homologous species. The principle embodied in the conception advanced by Prof. Cooke, and rightly regarded by him as of great importance to a correct science of mineralogy, he has named allomerism. It is evidently a case of homologous and isomorphous relations between members of a progressive series,—a general principle upon which I have insisted throughout the pages of this paper [one in the Compte Rendu of the French Academy of Sciences, for June 29, 1863, there reprinted,] and which includes the polymeric isomorphism of Scheerer."‡

§ 11. If now, as was argued in 1853–1855, the equivalent or integral weights of liquid and solid species are represented by

* Comptes Rendus de l'Académie des Sciences, xli, 1167; sur les rapports entre quelques composés different par H_2 et O_2. "Nous portent à admettre un rapport intime entre les corps différants par H_2."

† Cooke, this Journal, 1883, xxvi, 310–316, resuming the conclusions of his studies of 1855 and 1860.

‡ Hunt, Chemical and Geological Essays, 447.

very large numbers (which, as was subsequently shown, are multiples by many thousands of that of hydrogen) and if, as was then further maintained, there are found among such species bodies belonging to progressive series having as a common difference not only CH_2, OH_2 and OM, but M_2, H_2 and O, it becomes apparent that the chemical formulas of bodies so related may present ratios much less simple than those hitherto generally admitted. If, in fact, the relations perceived in surbasic salts, such as the so-called subnitrates and subsulphates, which differ among themselves by $n(MO)$ be extended to other compounds, and if oxyds with elevated formulas differ among themselves by nH_2, nM or nO we may have not only $n(MO)$, $n(M_3O_4)$, $n(M_2O_3$ and $n(MO_2)$ which, if $n=24$, will be

$$M_{24}O_{24} \text{ ---} M_{24}O_{32} \text{ ----} M_{24}O_{36} \text{ ----} M_{24}O_{48}$$

but bodies intermediate between these, the general formula being $M_{24}O_{24}+nO$. The coefficient of M for oxyds like periclase, magnetite, hematite, polianite, quartz and cassiterite, will however not be 24, but approximately 2400.

§ 12. The existence of oxyds of such intermediate composition has lately been insisted upon by Schützenberger, who shows that oxyds of tin, mercury, copper, lead, zinc, manganese and iron, when prepared in different ways, vary considerably in their proportions of oxygen. Thus cupric oxyd from the calcined nitrate evolves oxygen when dissolved in nitric acid, while ferric oxyd got by a similar process, if we assume the formula to be Fe_2O_3, gives the value of Fe=54, while for a similar oxyd from the calcined oxalate, if we admit the same formula, we get Fe=56. In other words, 24 parts of oxygen are in the first case united with 54, and in the second with 56 parts of iron.

Boutlerow, who confirms the results of Schützenberger, concludes from similar studies that the combining weight of carbon may vary from 12·0 to 11·8, and supposes a change in the chemical value of that element; that is to say, the amount of carbon united with 32 parts of oxygen may vary from 12·0 to 11·8 parts, the resulting compounds, though not identical, being similar in chemical properties. Schützenberger, in like manner, admits the variability in value on either side of a point of maximum stability, which is in most cases attained. He concludes that "all of these results lead directly to the conclusion that the law of definite proportions is not rigorously exact, unless we are willing to admit in each particular case the existence of compounds more or less oxygenized than those hitherto known to us, which may occur mixed with the products of the reaction."* This suggested explanation of the

* See for the papers of Schützenberger and Boutlerow, Bull. de la Société Chimique de Paris, 1883, xxxix., 257–263, also an extended analysis of them in this Journal, in the same year, xxvi, 63. The results obtained, according to

facts, which, however, does not appear to be acceptable to Schützenberger, Boutlerow, or Cooke (who has published a valuable discussion of the subject), is nevertheless an approximation to what we conceive to be the true one, believing however that the oxyds with more or less than the ordinary proportions of oxygen are not necessarily nor even probably (with some apparent exceptions) admixtures, but definite intermediate oxyds, being members of great progressive series.

§ 13. The conception that these variations in composition are due to the presence of admixed portions of more and less oxygenized compounds is not acceptable to Schützenberger for the evident reason that it becomes inadmissible when we have to deal with gaseous or vaporous species such as carbon dioxyd and as water-vapor. This, as generated by passing hydrogen gas over ignited copper oxyd, presents according to him, variations in the proportions of H : O, of from 1·00 : 7·95 to 1·00 : 8·15 by weight; that corresponding rigorously to the volumetric relation 2 : 1, being, from the most probable data, very nearly 1·00 : 7·98. Water thus obtained, with an excess of oxygen, though neutral, possesses, according to Schützenberger, oxydizing powers; the same being true of carbon dioxyd with the larger proportion of oxygen.

§ 14. Prof. Cooke, as we have seen (§ 10), had already in 1860, arrived at a conclusion similar to that subsequently reached by Schützenberger and by Boutlerow; namely, that "the law of definite proportions is not so absolute as has been hitherto supposed;" but that the chemical value of the elements may change within certain limits. In his discussion, in 1883 of these views as enunciated by the chemists just named, Cooke remarks—"Such opinions are certainly very revolutionary, and if they prevail must entirely change the fundamental conceptions of chemical philosophy. Chemical combination can no longer be regarded as the juxtaposition of the definite invariable masses which we call atoms, but must be considered as the 'reciprocal saturation' or 'interpenetration' of masses which may vary with the relative strength of their chemical energy acting at the time; and this change of the fundamental conception is inconsistent with the atomic theory, and with the superstructure which modern chemistry has built upon it." Cooke adds that while holding that "the atomic theory is the only basis on which a consistent philosophy can at present be built"—"he is rather drawn to that view of nature which refers all differences between substances to dynamical causes,

Schützenberger, "conduisent directement à cette conclusion, que la loi des proportions definies n'est pas rigoreuse, à moins qu'on ne veuille admettre dans chaque cas particulier l'existence des composés plus oxigénés on moins oxigénés que ceux connus jusqu' à présent, et qui se trouveraient en mélange avec le produit principal de la réaction."

and which regards the atomic theory as only a temporary expedient for representing the facts of chemistry to the mind."*

§ 15. It has already been shown that the writer does not share the interpretation of these variations in composition given by Cooke, Schützenberger and Boutlerow, but regards, as was already said in 1867, the facts "from which some have suggested a deviation from the law of definite proportions," as "only an expression of that law in a higher form;" believing that so far as we yet know, the laws of measure, number and weight in chemistry are invariable. To one who since 1853 has persistently combatted the atomic hypothesis as contrary to a sound philosophy,† and throughout all the succeeding years has sought to build up without it a new theory of chemistry upon a dynamic basis, it is however no small satisfaction to find that Prof. Cooke, who has been among the ablest defenders of this famous hypothesis, is at last led to look upon it as "only a temporary expedient for representing the facts of chemistry to the mind."

§ 16. The question here arises whether in gaseous species like water-vapor, H_2O, and carbon dioxyd CO_2, whose integral or equivalent weights are represented by these formulas, it is possible to admit such variations in composition as have been already signalized, and as we have sought to explain in the case of liquid and solid species of high equivalent weights. We recall what has been said (§ 2, § 4) as to the process of homogeneous dissociation when the hexad integer of sulphur vapor at 500° is changed at higher temperatures into three dyad integers, and the dyad integer of iodine is at 1500° disintegrated into two monad integers, as also the integrations of pentine and aldehyde, and the homogeneous disintegration of their so-called polymers; and again, the fact that the dyad integer of hydrogen (H_2), after combining integrally with a similar integer of chlorine (Cl_2), is dissociated into two dyad integers of chlorhydric gas, $2(HCl)_{11}$,—the double process of heterogeneous integration and homogeneous disintegration taking place without a perceptible interval, so that no change of volume is observed. The union of hydrogen and oxygen, in like manner, may be supposed to give rise temporarily to a more condensed vaporous species, which subsequently undergoes homogeneous disintegration or dissociation like sulphur and iodine vapors, or like H_2Cl_2, or dipentine $C_{10}H_{16} = 2(C_5H_8)$. Thus, while ordinary water-vapor, with the ratio for hydrogen and oxygen of 2 : 1 by volume, and of 1·0 : 7·9816 by weight, equals

* This Journal (1883) xxvi, 310, 316.

† A New Basis for Chemistry, pp. 60–67. See also in this connection G. A. Hirn, La cinétique moderne et le dynamisme de l'avenir; Comptes Rendus de l' Académie des Sciences, Sept. 20, 1886.

$(H_{100}O_{50}) \div 50$, the ratio $1{\cdot}0 : 8{\cdot}142$ corresponds to $(H_{100}O_{51}) \div 50$. These figures, arbitrarily assumed, will serve for illustration; but it may be remarked that the integral weight for the gaseous species, $H_{100}O_{51} = 898{\cdot}16$, which may be supposed to have a momentary existence before homogeneous disintegration, is not very much greater than the weights observed for the vapors of stannic and aluminic iodids; $SnI_4 = 534{\cdot}1$, and $Al_2I_6 = 813{\cdot}2$.

§ 17. The integral weight of liquid water with the usual volumetric ratios is represented by $1628(H_2O) = 29{,}244$, as has been shown at length in "A New Basis for Chemistry." The great importance of this datum is due to the fact that the weight of this liquid at its maximum density has, for obvious reasons, been assumed as the unit of specific gravity for all liquids and solids. For similar reasons of convenience, a second arbitrary unit, the weight of atmospheric air at 0° and 760^{mm} pressure, has been adopted as the unit of specific gravity for all gases and vapors. Hydrogen gas at the same temperature and pressure, which gives us the unit of integral weight, would, however, seem to be the natural unit of specific gravity for all bodies whatsoever, and in fact the accepted integral or equivalent weights for gases and vapors are but the specific gravities of these bodies referred to hydrogen, $H_2 = 2{\cdot}0$; which is not only the unit of weight and volume adopted by chemists for all gases and vapors, but also the unit of weight in all calculations of the equivalent or integral weights of liquid and solid species. The values thus assigned not only to water-vapor and to gaseous carbon dioxyd, but to ice, to water, to liquid and solid carbon dioxyd, to quartz, and to calcite, are really the specific gravities—hydrogen gas, $H_2 = 2{\cdot}0$ being unity—of the normal gaseous species H_2O and CO_2, and of the possible gaseous species, silicon dioxyd, SiO_2, and calcium carbonate $CCaO_3$, which by integration, or so-called polymerization, give rise to the liquid and solid forms of water and carbon dioxyd, to tridymite and quartz, to calcite and aragonite.

If now we compare the densities of these various liquid and solid species with those of the known gaseous species H_2O and CO_2, or, in the last analysis, with the density of the hydrogen unit, H_2, we obtain a direct expression for the condensation suffered by these in passing into the liquid and solid integers. In other words, we get the specific gravity of these bodies, the dyad integer of hydrogen at 0° and $760^{mm}(H_2 = 2{\cdot}0)$ being unity. That of water-vapor at 100° and 760^{mm}, represented by $H_2O = 17{\cdot}9633$; the same volume of water at 100° being represented by $1628(H_2O) = 29{,}244$. The density of all species, whether gaseous, liquid or solid, is thus compared with that of their volumetric equivalent of hydrogen gas $(H_2 = 2{\cdot}0)$ at the standard temperature and pressure, and is seen to be for

liquids and solids, not less than for gases and vapors, a function of their equivalent or integral weights.

§ 18. The hardness and chemical indifference of solid species are in like manner, as we have elsewhere endeavored to show, functions of their integral weights. For the study of these relations we have calculated for the species to be compared the values got by the proportion $d:p::1:v$, in which d = density of weight of the liquid or solid species compared with water, $1628(H_2O)$ at 4°; and p = the weight of the gaseous species (or so-called molecular weight) compared with H_2 at 0° and 760^mm^. The relation $d:p$ is thus that between the densities of the solid (or liquid) and the gaseous species, and the so-called molecular volume = v is the reciprocal of the co-efficient of the condensation suffered by the gaseous in passing into the solid species. The hardness and the chemical indifference of related species are inversely as the values of v.

For such species, with more or less complex formulas, it becomes necessary to fix comparable terms for p, and in the case of compound oxydized species, of which the vapor-density is unknown, we have assumed, as the unit for p, a weight including that of H = 1·0, of Cl = 35·5, or of O÷2 = 8·0. By thus adopting a combining weight of 8·0 for oxygen as a basis, we get a unit which gives a common term of comparison for oxyds, sulphids, chlorids, fluorids, and for intermediate compounds like the oxysulphids and oxyfluorids common in native species. It is of course a hypothetical unit, which for elemental species and, for fluorids, chlorids, etc., corresponds with the normal vaporous species; but for oxydized species is some fraction thereof, as in the cases of water, of spinels, and other oxyds.

We may readily extend this system of hypothetical units to silicates, carbonates, sulphates, phosphates and more complex species by dividing in all cases the empirical equivalent weight by twice the number of oxygen portions (O = 16·0, or more exactly 15·9633) plus the number of chlorine or fluorine portions.* We have thus, for example:

		p.
Forsterite,	$SiMg_2O_4 = 140 \div 8$	17·50
Calcium carbonate	$CCaO_3 = 100 \div 6$	16·66
Calcium sulphate	$SCaO_4 = 136 \div 8$	17·00
Gypsum	$SCaO_4 \cdot 2(H_2O) = 172 \div 12$	14·33
Apatite	$3(P_2Ca_3O_8) \cdot CaF_2 = 908 \div 50$	18·16

* In the writer's essay on A Natural System in Mineralogy (Mineral Physiology and Physiography, 279–401), the values of p and v have been thus determined. These silicates are there represented by a new notation, which employs symbols in small letters to represent quantivalent ratios; the combining weights of the elements being divided by their valency, and in all cases followed by their coefficients. The formula of forsterite thus becomes $(mg_1si_1)o_2$, that of orthoclase $(k_1al_3si_{12})o_{16}$, and that of topaz $(al_3si_2)o_4f^1$.

§ 19. Such fractional units are convenient for the purpose of comparing the varying condensation in species belonging to the respective groups, but it will be borne in mind that in order to construct formulas which shall represent the true equivalent weights of liquid and solid species, we must multiply instead of divide the formulas hitherto accepted as representing the normal species. The combining weight of these must be the unit for fixing the equivalent weights and the true formulas of such liquid and solid species; which are generated by integration or polymerization from the normal species. This, though known to us in the volatile elements, and in compounds like carbon dioxyd, water-vapor, formic and acetic aldehydes and pentine, is unknown in the case of bodies like carbon, silicon, silicon dioxyd, and most of the solid oxyds; as also in the various silicates, carbonates, sulphates and phosphates. For all these we choose, as representing the normal species, the simplest formula which satisfies the relations of valency, and which corresponds to the theoretical gaseous or volatile species.

The writer has sought in the preceding pages to illustrate and set forth in detail several points which were more briefly noticed in his lately published volume entitled "A New Basis for Chemistry," to which this paper may be considered as a supplement.

ART. XV.—*Verification of Tornado Predictions;* by H. ALLEN HAZEN.*

IN taking up the study of the verification of tornado predictions, we must carry in mind the exact words of the prediction which are: "Conditions are favorable for the development of tornadoes in region . . . ." It is generally understood that in these predictions the country east of the 102° meridian is divided into eighteen districts, and tornadoes are predicted for in each of these. For the present study the predictions for the month of June, 1885, are to be discussed. One scheme of verification that has been suggested is that of Prof. Gilbert, of the Geological Survey, published in *American Meteorological Journal* for September, 1884. Prof. Gilbert divides the predictions and occurrences into three general classes. 1. Suc-

* In the number of the *American Meteorological Journal* for July, 1884, Mr. Finley published a statement as to success in tornado prediction claiming over 97 per cent. This statement aroused quite a lively discussion in Science and other journals, notably one by Prof. Gilbert, in which he credited Mr. Finley with 23 per cent. In October, 1885, several persons were desired by Mr. Finley to take up the discussion, and the following paper is now presented as written then, it having been found impossible to publish it before this, through circumstances beyond the writer's control.—Washington, D. C., July 4, 1887.

cessful predictions. 2. Unsuccessful ones. 3. Failures to predict. In other words, every district in which a tornado occurred as predicted counted as one in favor of the predictor in the final summing up, and each district which did not have a tornado as predicted for, together with each district in which a tornado occurred which was not predicted, counted as one against the predictor. Taking the predictions of tornadoes for the month of June, 1885, and summing the three classes in the table, we find 8 successful; 32 unsuccessful; and 13 failures to predict: total, 53. This (according to Prof. Gilbert) gives a verification of 15 per cent for the predictions as made. It seems as though this method of verification is open to most serious objections, some of which may be enumerated as follows:

1. The verification depends on the occurrence of a tornado anywhere within an imaginary line and does not make any allowance for the nearness to that line, e. g., if a tornado should occur just at the edge or within five miles of the district for which it was predicted, it would count as *two* against the predictor, or if we should simply verify for that single prediction we would find a difference of 100 per cent. in the verification in going five miles, just across the imaginary line from one district into another. As an illustration of this, we may take a prediction of rain for the central of three contiguous districts, and as a system of verification we may adopt the principle that the occurrence of rain in any district where it was predicted shall be a success, and its occurrence in a district not predicted for shall count as a failure. In the case before us, let rain be predicted for the central district, and let it fall almost over the whole of it but lap a little on the districts to the right and left. According to the principles adopted, we would have one successful prediction and two failures and a verification of 33 per cent, while it must be admitted that any rational system of verification would allow a success of at least 90 per cent for such a prediction.

2. We cannot assume that all the tornadoes have been heard from in each district.

3. It is extremely difficult to distinguish between tornadoes and destructive storms, as one may merge into the other.

4. If there be any law in the occurrence of tornadoes, we would certainly expect that they will have a tendency to greater frequency in certain portions of an atmospheric disturbance, and if they occur outside of those portions that they will be more or less sporadic. The above system, however, regards all tornadoes precisely alike and gives no more weight to the occurrence of five in a district predicted for, than to the occurrence of one, perhaps of half the intensity of each of the other

five, which has occurred in a district not predicted for. We certainly cannot regard the occurrence of a tornado of so definite a nature, as, for example, a rifle-ball from a marksman's rifle, and we ought not to apply a method of verification which would be perfectly proper in the case of rifle-balls and a target to one utterly dissimilar.

5. No account is taken of the fact that the law of occurrence of tornadoes is very different in one portion of the country from that in another; for example, conditions which would almost invariably produce a tornado in the Mississippi valley would not be at all efficient in the region east of the Allegheny Mountains or in Texas.

6. It is entirely unsatisfactory to group together districts where only one tornado occurs in a year with those where thirty or more occur each year. This may be better seen by a slight exaggeration. Suppose we have a district where only one tornado occurs in ten years, it is very plain that a very good knowledge of the laws of tornado occurrence would be of little avail in predicting for such a region, and the chances of getting even one per cent. would be exceeding small, while if there were a region having 100 tornadoes in a single year, the chances of getting 50 per cent would be much better than of getting 1 per cent in the previous case.

In seeking for a satisfactory system of verification it should be distinctly borne in mind that the character of the occurrence is very indefinite and that we cannot apply rigid mathematical analysis to the questions, but must seek for a rational system which will best treat the prediction as worded and an occurrence so indefinite.

In seeking such a system I have carefully studied the occurrence of tornadoes and destructive storms, and have found the following comprise all the districts having more than thirty storms each: (No. 5) 35, (6) 35, (7) 35, (8) 30, (9) 35, (11) 35, (12) 35, (13) 60, (14) 40, (15) 32. Of these districts there are 3 in which the occurrence of tornadoes can hardly be said to be under precisely the same laws as in the rest; these are 5, 8 and 12. It has seemed wise to include in the discussion, though with less weight, hurricanes and destructive storms. As a working hypothesis, I have assumed that tornadoes occurring in a district half way between the center and edge shall have weight 1; in the rest of the district $\frac{3}{4}$; to the center of the district next outside $\frac{1}{2}$; to the outside of that $\frac{1}{4}$; all outside of these 0. A study of the predictions and occurrences has developed an approximate result as in the last column of the table herewith and a percentage of verification of 49.

TABLE.

Prediction, occurrence, and non-occurrence of tornadoes by Mr. Finley, for June, 1885.

	DISTRICTS.					SUCCESS.
Day.	Predicted for.	Occurred in.	Successful.	Unsuccessful.	Failures.	By weight.
2	9, 15	13		2	1	1, $\frac{1}{2}$, $\frac{1}{2}$
3	13, 15	15, 13	2			$\frac{3}{4}$, $\frac{3}{4}$
4	9,			1		$\frac{3}{4}$
5	2, 4	16		2	1	
6	15, 16, 18, 17, 12			5		0
7	8, 9, 12, 13	15, 8	1	3	1	$\frac{1}{2}$, $\frac{1}{2}$
8	5, 6, 4, 7, 12			5		0, 0, 0
9	12, 11			2		0
12	13, 14, 15, 16	18, 16, 15	2	2	1	$\frac{1}{2}$, $\frac{1}{2}$, 1
13	15, 16			2		$\frac{1}{2}$
14	13, 9, 15	16, 15	1	2	1	1, $\frac{3}{4}$, 1, $\frac{1}{2}$
15	15, 17			2		$\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{2}$
19	14				1	0
20	13, 16	14, 13	1	1	1	1, $\frac{1}{2}$
21	8, 2	14, 13, 8	1	1	2	0, 0, $\frac{1}{2}$
22	1	12, 2		1	2	
27	16	18, 15		1	2	$\frac{1}{2}$
						0, $\frac{1}{2}$, $\frac{3}{4}$, 1
Total,			8	32	13	8, 13, 5, 5

By weights. Total, 31 cases, $15\frac{1}{4}$ success. Verification, 49 per cent.

A better knowledge of the degree of destructiveness of the storms would give much more rigid results. I have also refrained from giving the occurrence of a large number in any district as much weight as they should have; this would have given a slightly higher percentage of success.

There is also another important question that I have not touched upon, it is this: The occurrence of tornadoes in any districts must necessarily be connected with their non-occurrence, i. e., given a large number of districts in which tornadoes are possible, if one had a perfect knowledge of the laws governing the occurrence of tornadoes he would be forced to state or infer that in certain portions of these districts they would *not* occur, where to the uninitiated there would be an equal probability of occurrence or non-occurrence. Now, since it is difficult to decide what the probability of occurrence is, it would be well nigh impossible to assign a proper weight to a given occurrence, but one thing would certainly seem eminently just and that is that if in any district contiguous to one in which a tornado is predicted, the occurrence of a tornado not predicted receives full weight against a predictor, then the non-occurrence of one in a neighboring district not predicted for should have equal or nearly equal weight in favor of the predictor. It will be seen that if an allowance of the above nature be admitted the 49 per cent already found will be somewhat increased.

It may be objected, however, that the probability of any tornado occurring at all is so small, that the probability that one will occur in any one of the districts not predicted for is entirely overborne by the former consideration. This objection, however, is only plausible. If we should take the occurrence of a tornado on any single day of a year as a criterion, it must be admitted that the probability of such occurrence is very slight, but in the case before us we are not considering the occurrence of a tornado on any one of 365 days but rather on any one of, say, 50 special days when they are very likely to occur. It is easy to see that in this case the probability that a tornado will occur in any one of a large number of districts, on any one of a small number of special days, exceedingly favorable for its development, is vastly greater than the general haphazard guess that one will occur on any day of the year and especially on an unfavorable day. It seems as though this important principle has been overlooked in the general discussions of this question.

It seems probable that the division of the country into districts, in each of which predictions are to be made, is hardly wise. The whole subject is still on the border-line of uncertainty and indefiniteness. Possibly it would be more satisfactory to predict, in a region where at least 25 or 30 destructive storms and tornadoes occur each year, a central point or locus of destructive storms, giving boundaries, more or less definite, to the limit of destruction, and in verifying to give weights to storms occurring at distances of 50, 100, etc., miles from that locus. It is also essential that we pay the closest attention not to the probability of a tornado occurring on any day in general, but rather to the probability of its occurring on any one of a few special days when the general meteorological conditions and our knowledge of the laws of such storms (for example, their occurring in the southeast quadrant of a low area), would lead us to infer that they are extremely likely to occur.

Dec. 4, 1885.

ART. XVI.—*Studies in the Mica Group*; by F. W. CLARKE.

I. *Muscovite from Alexander County, N. C.*

THIS mica occurs in overlapping, crystalline plates, implanted edgewise in pockets at the well-known locality for emerald and hiddenite at Stony Point. The plates are several centimeters in diameter, with sharply defined crystalline boundaries; and in the specimens before me they are associated with crystallized dolomite, pyrite, and rutile. All of these minerals are more or

less dusted over with a dark-green chloritic coating, which together with some ferruginous staining, gives the mica a somewhat bronzy appearance. An analysis made upon carefully purified material gave the following results:

Ignition	5·46
SiO_2	45·40
TiO_2	1·10
Al_2O_3	33·66
Fe_2O_3	2·36
MgO	1·86
CaO	none
Li_2O	trace
Na_2O	1·41
K_2O	8·33
F	·69
	100·27
Less oxygen	·29
	99·98

This, except for the presence of titanium, is the composition of an ordinary muscovite. Possibly the titanium may be due to minute inclusions of rutile, but none such were detected. It is more probably present as a replacement either of silica or of alumina.

One of the smaller plates of this mica was examined microscopically by Mr. J. S. Diller, who has kindly furnished the subjoined notes:

"The group of muscovite scales shows well-defined crystallographic outlines, most prominent among which are the clinopinacoid and the unit prism, although a small clinodiagonal prism is also common. Parallel with the latter there are indistinct cleavage lines, which in the basal plane make an angle of 31° with the edge between the basal plane and the clinopinacoid. The angle of the optic axes, measured in oil in a plane perpendicular to the plane of symmetry, is 35°.

"The muscovite is partially coated by a greenish dust, which in its arrangement follows crystallographic lines, giving to the scales a streaked appearance. It appears most abundantly upon the prismatic edges, but to a considerable extent also upon the clinopinacoid, and in traces on the clinodiagonal. Thin laminæ occur between the foliæ of the muscovite, to which it imparts a yellowish tinge in reflected light. It appears to be weakly doubly refracting, but its structureless character and want of definite optical properties render its determination a matter of difficulty."

With some trouble I collected a little of this chloritic dust

0·3165 gram in all, and made a partial analysis of it as follows:

Ignition	20·50	
SiO_2	31·16	
Al_2O_3	8·06	
Fe_2O_3	35·86	=32·28 FeO.
MgO	5·43	
	101·01	

The iron is undoubtedly present chiefly, but not wholly in the ferrous state; and the alumina is ascribable to traces of admixed mica. Still, with all its defects, the analysis clearly defines the mineral as a member of the obscure hisingerite group, which has rarely been noted in this country. Its association with pyrite is similar to some of its occurrences abroad, and here, as observed elsewhere, it may originate in the alteration of that species. I hope to give it a fuller examination sometime, with a larger supply of material. For the specimens so far studied I am indebted to the kindness of Mr. Wm. Earl Hidden.

2. *Lepidomelane from Baltimore, Md., and Litchfield, Maine.*

Baltimore Lepidomelane.—This mineral, the characteristic black mica of the Jones Falls pegmatite, was sent me for analysis by Dr. G. H. Williams of the Johns Hopkins University. The specimen submitted was in broad, brilliant foliations, black by reflected, but dark smoky green by transmitted light. According to Dr. Williams it is very nearly uniaxial. In the following analysis (I.) the direct estimation of water and the determination of ferrous iron were made by Mr. R. B. Riggs.

Reckoning the water with the alkalies, the analysis gives approximately the formula $R'_6R''_3R'''_4Si_5O_{22}$. It is, therefore, slightly too basic for an ordinary orthosilicate, and it seems to occupy an intermediate position, as do its ratios, between annite and the Litchfield lepidomelane.

	I. Baltimore.	II. Litchfield.	
H_2O	4·48	4·67	
SiO_2	35·78	32·35	
Al_2O_3	16·39	17·47	
Fe_2O_3	14·55	24·22	
FeO	11·02	13·11	
MnO	1·08	1·02	
CaO	none	·89	
MgO	8·67	none	
K_2O	7·76	·70	
Na_2O	·56	6·40	
TiO_3	none	none	
	100·29	100·83	Fluorine none.

Litchfield Lepidomelane.—In a previous paper upon the minerals of Litchfield,* I gave an analysis of this mica, together with some data as to its occurrence. It is scattered abundantly through the elæolite syenite of the locality, in black, brilliant plates or scales, which are transparent only in very thin laminæ, and then transmit light of a dark green color. It is one of the least transparent micas I have ever seen. According to Mr. Diller, who kindly made a microscopic examination of the mineral, it is so nearly uniaxial that a measurement of its optic-axial angle is impracticable. Some specimens show evidence of two micas; one being blacker and more brittle than the other; so that a new analysis was made upon very carefully selected material. Only the more transparent and elastic foliæ were chosen, and the results are given on the preceding page (II).

The ferrous iron and water determinations were made by Mr. Riggs. Titanium was carefully sought for, by two methods, in three separate tests; but only a doubtful trace was discovered. The formula of the mica, reckoning water with the alkalies, is very nearly $R'_6R''_2R'''_6Si_5O_{24}$.

This mica, on account of its low percentage of silica and its basic nature, has peculiar interest. Among published analyses of micas I find only two which approach it in these particulars, namely, the micas from Brevig and Miask described by Rammelsberg.† These gave respectively 32·97 and 32·49 per cent of silica, but they also contained, the first 2·42 and the second 4·03 of titanic oxide. This constituent, as has been stated, is lacking in the Litchfield mineral. Notably all three of these low-silica micas are from localities of elæolite syenite; although Rammelsberg says nothing of the actual associations of the specimens discussed by him. The question at once arises, to be settled by future investigation, whether micas of this peculiar character are representative of elæolitic rocks, and whether there is any genetic relation between them and elæolite. I hope that observations upon this point may soon be multiplied.

Some months ago I published some analyses of the Rockport micas, which were made by Mr. Riggs in this laboratory.‡ One of these, the so-called annite, seems to have a serial relation with the analogous micas from Baltimore and Litchfield, which may be expressed in formulae. These, stated in empirical form, are as follows:

Rockport ....$R'_6R''_4R'''_2Si_5O_{20}$
Baltimore............$R'_6R''_3R'''_4Si_5O_{22}$
Litchfield.... ......$R'_6R''_2R'''_6Si_5O_{24}$

Here we have R′ and silicon constant, while a gain of R'''_2O_3

* This Journal, April, 1886.
† Zeitschr. Geol. Gesell., xxxi, 676.
‡ This Journal for Nov. 1886.

corresponds in each step to a loss of one atom of R''. If now we assume that R'''_2O_2 represents really two of the recognized univalent groups $-Al=O$, we shall find that all three of the micas reduce to the true orthosilicate type, containing the nucleus $R'''_2(SiO_4)_5$, which appears to be characteristic of many iron micas and of the phlogopite group. We thus have, uniting all the monoxide bases, the following general formulæ:

Rockport .... $R'_{14}R'''_2(SiO_4)_5$
Baltimore .... $R'_{12}(AlO)_2R'''_2(SiO_4)_5$
Litchfield .... $R'_{10}(AlO)_4R'''_2(SiO_4)_5$

In short, the three micas are built upon the same fundamental plan, and exhibit a new and highly suggestive order of variation.

3. *Iron-Biotite from Auburn, Maine.*

Among the minerals occurring at the well-known lepidolite locality at Auburn, a brilliant black biotite is common. Some time since, in looking over a collection of the Auburn material in the possession of Mr. N. H. Perry, of South Paris, I observed that certain broad foliæ of this mica were bordered by a grayish, distinct margin, about five millimeters wide, which was made up of micaceous scales. Inasmuch as the lepidolite of the locality forms similar borders upon the muscovite, I thought that this bordering might have interest, and Mr. Perry kindly placed his best specimen at my disposal. Analyses of both the biotite and the margin were made, but unfortunately the amount of the latter available was too small for complete investigation. In the study of the border, therefore, ferrous iron and water had to be neglected, and that analysis is so far incomplete. The results are given below, with determinations of water and ferrous iron in the biotite, made by Mr. Riggs:

	Biotite.	Margin.
H_2O	4·64	undet.
SiO_2	34·67	56·44
Al_2O_3	30·09	16·01
Fe_2O_3	2·42	15·91
FeO	16·14	
MnO	·85	undet.
MgO	1·98	·97
CaO	none	none
Na_2O	1·67	1·92
K_2O	7·55	6·15
F	·28	·71
	100·29	
Less oxygen	·12	
	100·17	

Upon microscopic examination by Mr. Diller, the mica was found to be "almost completely uniaxial, for when it was rotated between crossed nicols the displacement of the black cross was scarcely perceptible." He also found that the same mica, with a slight change of color from brown to greenish brown, continued into the border; where it was intimately mingled with grains and fibers of quartz. The latter admixture accounts in part for the high percentage of silver in the margin; although it seems probable that there may be also some degradation from the original orthosilicate toward a metasilicate type. At all events the specimens are in nowise analogous to those which show lepidolite borders upon muscovite.

In its ratios this Auburn mica is not simple. Approximately, reducing all monoxides to the univalent type, its formula may be written $R'_{11}(AlO)_3Al_2(SiO_4)_5$; with $R'_{11}=H_4K_2Fe_{2\frac{1}{2}}$. It seems to be a compound intermediate between the Litchfield and Baltimore micas, with R''' nearly all aluminum.

4. *Iron-Mica from near Pike's Peak.*

This specimen, which was kindly given me by Mr. C. S. Bement, was a section from a large prismatic crystal in his collection. It was a bronzy black mica, resembling phlogopite externally, but remarkably altered at the center. The entire core of the crystal was made up of a soft, rotten material, evidently derived from the original mica, and surrounded by a broad, black margin of the latter. Streaks of rusty alteration products reached into the margin in every direction, so that no absolutely unchanged material could be obtained for analysis. According to Mr. Diller, the angle of the optic axes is too small for measurement.

Analyses were made of both margin and center, the former being as little altered, the latter as much altered as could be selected.

Again I am indebted to Mr. Riggs for determinations of water and ferrous iron:

	Margin.		Center.
H_2O	4·54	Ignition	7·82
SiO_2	34·21		34·63
Al_2O_3	16·53		17·95
Fe_2O_3	20·15		31·25
FeO	14·17		3·01
MnO	·91		·34
CaO	·48		·81
MgO	1·34		1·08
Na_2O	1·43		·89
K_2O	6·50		1·96

F	·08	·54
	100·34	100·28
Less O	·03	·23
	100·31	100·05

These figures show the order of alteration so well that comment upon them is unnecessary. The original mica probably was very near Lewis's siderophyllite, but it is hardly worth while to discuss the ratios.

Laboratory U. S. Geological Survey, Washington, May 2, 1887.

ART. XVII.—*On the Serpentine (Peridotite) occurring in the Onondaga Salt-group at Syracuse, N. Y.*; by GEORGE H. WILLIAMS.

(Paper read before the National Academy at Washington, April 20, 1887.)

ABOUT the year 1837 there was discovered on the side of the hill just east of what was then the town of Syracuse, N. Y., a narrow and apparently horizontal bed of a dark colored rock, which presented a striking contrast to the lighter colored shales and porous limestones both above and below it. The late Professor Oren Root of Hamilton College, was at that time the principal of the Syracuse academy, and the unusual, massive rock interested him so much that he used often to take his students with him to the locality to collect specimens. He readily recognized the rock as a typical serpentine and first brought it to the attention of Professor Vanuxem, who was then engaged upon the geological survey of this part of the State.

The exact locality where this serpentine appeared is now occupied by the lawn of Mr. Howard G. White. The band extended from what is now the center of James street, nearly across the lawn to where the house stands. It was for the most part a disintegrated, dark-green, earthy mass, through which large nodular blocks of the less altered rock were scattered.*

Vanuxem described this serpentine in his Third Annual Report in 1839, and in his final volume on the Geology of the Third District of New York in 1842. Dr. Lewis Beck also mentions it in his report on the Mineralogy of New York in

* For these and some other details the writer is indebted to the kindness of Mr. J. Forman Wilkinson, of Syracuse, who was one of Professor Root's pupils in the old academy. A large portion of his letter on the subject has been published in "Science" for March 11th, 1887. The localities given by Vanuxem and Beck are both different, but neither of them are so accurate as that above mentioned.

1842. The geological position of the serpentine, as defined by Vanuxem, has been so well summarized by Dr. T. Sterry Hunt in his recently published volume of essays,* that no further account of it need here be given, but Vanuxem's descriptions of the rocks themselves are so true that I cannot forbear quoting some of them. In a supplement to his Third Annual Report of 1839 he says: "The green and trap-like rocks observed near the top of the hill to the east of Syracuse have been examined so far as time would admit. They are all serpentines, more or less impure, and of various shades of bottle-green, black, gray, etc. . . . . Some have a peculiar appearance, like bronze, owing to small gold-like particles, with a lamellar structure, resembling bronzite or metalloidal diallage; also other particles, highly translucent, like precious serpentine, with frequently small nuclei, resembling devitrifications or porcellanites, colored white, yellow, blood-red, variegated, etc." In his final report (p. 109) he mentions the occurrence of both black and white mica and "accretions resembling granite." In one case hornblende replaced the mica producing an apparent "syenite." He also speaks of "calcareous accretions enveloped in the serpentine."

In 1858 Dr. T. Sterry Hunt published an analysis of a specimen of the Syracuse serpentine which he had obtained from Professor James Hall, of Albany.† This contained 34·77 per cent carbonate of lime, 2·73 per cent carbonate of magnesia and 62·5 per cent serpentine. This latter was found to have the following composition:

SiO_2	40·67
Al_2O_3	5·13
FeO	8·12
MgO	32·61
H_2O	12·77
	99·30

No traces of nickel or chrome were detected.

The Syracuse serpentine was also mentioned by the Hon. Geo. Geddes in his Report on the Agricultural Industry of Onondaga County,‡ and Prof. James D. Dana, in his Manual of Geology.§ It has recently acquired an additional interest on account of the argument for the origin of serpentine by chemical precipitation based upon it by Dr. Hunt.‖ Vanuxem

* Mineral Physiology and Physiography, 1886, pp. 443–447.

† This Journal, II, xxvi, p. 237, Sept. 1858.

‡ Transactions of the N. Y. State Agricultural Society for 1859.

§ Third Edition, 1880, p. 233.

‖ "The Geological History of Serpentines." Transactions of the Royal Society of Canada, vol. i, p. 174, 1883, and Mineral Physiology and Physiography, 1886, p. 443.

says of the Syracuse serpentine, (Final Report, p. 110): "The great interest of all these metamorphic products is that they have not been caused by a dry heat or fire, no evidence of the kind existing; nor is any needed to effect the change there observed, though it can and has and does produce the same result. All that is required is the presence of the elements of the products observed at Syracuse and in a state admitting of solution and of moisture, to which every degree of heat added would greatly aid their mutual action upon each other; and from solution crystallization would take place, and thus metamorphic products or rocks would be formed, no igneous action, commonly so called, being requisite, but a thermal one only." Dr. Hunt also says after discussing this occurrence (l. c., § 34, pp. 447 and 448): "From a study of the facts before us, it is apparent that we have here evidence of the formation by aqueous deposition of a bed of concretionary silicate of magnesia, taking the form of serpentine, with a little associated bastite or bronzite, and probably some other crystalline silicates."

It is therefore plain that the main point of interest connected with this now inaccessible occurrence of a typical serpentine relates to its mode of origin.

Through the liberality of Professor Albert H. Chester of Hamilton College, the original collections of the Syracuse rock, made by Professor Root while he was principal of the Syracuse Academy, have been placed in the writer's hands for study. This abundant and representative material, from which, however, the micaceous (granitic) and hornblendic (syenitic) accretions mentioned by Prof. Vanuxem are unfortunately absent, has been subjected to a thorough microscopical examination and it is the aim of the present paper to show that all the facts heretofore observed and stated by former investigators are perfectly in accord with the igneous origin of this rock; while certain other facts, here mentioned for the first time, place it almost beyond doubt that the serpentine was, in its original state, an intrusive mass, and *not* an aqueous deposit.

A macroscopical examination shows that the serpentine itself is represented by two quite distinct types. One of these is a very dark-green, almost black, rock, filled with minute glistening specks which the lens at once reveals as mica. Occasional larger plates of a brass-yellow color are also seen (4 × 6 mm.), and a more careful search discovers a few small masses of a lighter green, more compact serpentine with a sharp crystal-form.

The second type has a lighter color than the last. It is composed of a dense compact base which incloses numerous lighter spots with a sharp crystal outline, thus producing a decidedly

porphyritic structure. The irregular blood-red patches spoken of by Vanuxem are scattered through this rock. The porphyritic crystals here mentioned produce what Dr. Hunt has called the "concretionary structure" of the serpentine.

Under the microscope the rock of the *first type* appears as a medium-grained aggregate of brown mica, octahedral crystals of both a yellow transparent, and of an opaque black mineral, green or colorless serpentine and carbonates. Occasional larger crystal-forms are scattered through this matrix. It is remarkable that, in spite of nearly all the substance of this rock being secondary, the original structure is almost perfectly preserved. Sharply defined crystal-forms show by their shape that they must have once been *olivine* or *enstatite*, although none of the original substance now remains except rarely in the case of enstatite. The *mica* is that peculiar brown biotite which is well known to be characteristic of the eruptive peridotites.* It is without crystal-form, and often shows a peripheral zone of a lighter color due to bleaching. The minute octahedral crystals mentioned above are from ·05 to ·005mm. in diameter. The opaque black ones are for the most part *chromite*, although some of them may be *magnetite*, as the magnet shows that there is a little of this substance in the rock. If the serpentine powder be treated with hydrofluoric or with concentrated sulphuric acid, everything is dissolved except these small black octahedrons, which give a strong chromium reaction in both the phosphorous and borax beads. There is therefore little doubt that they are mostly chromite.

The little transparent yellow crystals entirely disappeared when the rock was treated with either of the above mentioned acids, and the solution in each case gave a strong titanium reaction with H_2O_2. This, together with the fact that they showed an isotropic character when examined in polarized light, suggested the possibility of their being *perofskite*, and such upon further investigation proved to be the case. In spite of the frequently repeated assertion in mineralogies that perofskite is not attacked by acids, it is well-known that it is dissolved by concentrated sulphuric acid, as stated by Dana† and Rosenbusch.‡ That it must also be attacked by hydrofluoric acid is shown by the fact that both Baumhauer§ and Ben Saude‖ used this reagent in a dilute form to produce etched figures on the planes of perofskite crystals. Stelzner¶ also found that it was impossible to isolate the minute octahedrons of perofskite from

* Vid. Rosenbusch: Die massigen Gesteine, 2d ed., 1886, p. 259.
† System of Mineralogy, 5th ed., p. 146.
‡ Die petrographisch wichtigen Mineralien, 2d ed., p. 295.
§ Zeitschrift für Krystallographie, Bd. iv, p. 187, 1880.
‖ Ueber den Perowskit, Göttingen, 1882, p. 22.
¶ Neues Jahrbuch für Mineralogie, etc.,II Beilage Bd., p. 392.

the melilite basalt of Hochbohl by hydrofluoric acid. The method proposed by this latter investigator was therefore made use of in the present case with complete success. The finely powdered rock was digested for a long time in concentrated hydrochloric acid under pressure, and all the components dissolved except the octahedral crystals and the mica. These were separated by washing until finally a powder was secured which the microscope showed was composed of the black and yellow crystals in about equal proportions along with a small amount of the brown magnesia mica. This powder, which was found to weigh ·0442 gr., was then treated with strong sulphuric acid, in which ·0277 gr., of the chromite remained undissolved. A quantitative analysis of the filtrate, containing only ·0165 gr., was kindly made for me by Mr. J. H. Kastle, of the chemical laboratory of the University with the following result:

TiO_2	34·54
CaO	12·12
FeO	54·54
	101·20

This analysis can only be regarded as an approximation on account of the extremely small amount of material at command. Mr. Kastle says that the iron is undoubtedly too high. What of this substance is present is partly contained in the perofskite, isomorphous with CaO; partly derived from the mica which is dissolved by sulphuric acid. The above proportion of CaO puts the nature of the mineral as perofskite beyond a doubt, as no other mineral is present which contains a trace of lime. Moreover any other titanium mineral, as for instance anatase,* would not have been completely dissolved by sulphuric and hydrofluoric acids.

Perofskite was first recognized as a rock constituent in 1876 by Boricky† in the nepheline basalt of Wartenberg in Bohemia. In 1878, Hussak‡ discovered it in the basalt lava of Scharteberg in the Eifel, and in 1883, it was isolated and analyzed from the melilite basalt of Hochbohl by Stelzner.§ In all of these cases the crystals were simple octahedrons, and Hussak describes them as doubly refracting, like most of the larger crystals of this species. Sauer‖ has recently described large crystals showing the cube and octahedron in the coarse veins of the nepheline-basalt from Wiesenthal in Saxony.

* The suggestion was ventured in the preliminary description of the Syracuse serpentine, published in "Science" of March 11th, that these crystals might be anatase.

† Sitzungsber. d. böhm. Ak. d. Wiss., 1876.

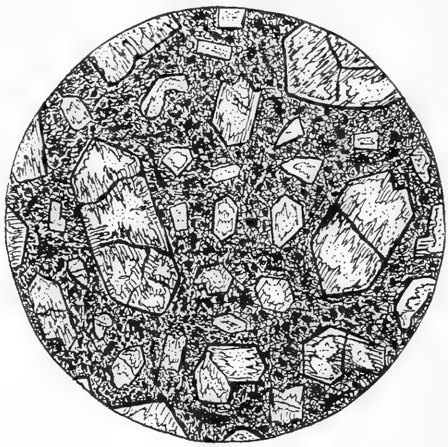
‡ Sitzungsber. d. Ak. der Wiss. in Wien., April, 1878.

§ Neues Jahrbuch für Mineralogie, etc., II Beilage Bd., p. 390.

‖ Zeitschrift d. deutsch. geol. Gesellschaft, xxxviii, 1885, p. 441.

The occurrence of perofskite in the Syracuse serpentine is in all respects identical with that in the rocks described by Boricky, Hussak and Stelzner, specimens of which have been carefully examined for comparison. It is interesting as being the first instance on record of perofskite as a constituent of any American rock, and also as the first discovery of perofskite in a peridotite or serpentine from any locality.

The porphyritic type of the Syracuse serpentine is essentially identical with that above described in all points except its structure. The groundmass is finer grained, which throws the characteristic crystal-forms of the olivine and enstatite into a sharp relief. The structure of this rock is represented



in the accompanying figure. The octahedral crystals are much smaller than in the other rock and are confined wholly to the groundmass. The brown mica is here much less abundant. The porphyritic olivines especially are most representative examples of the well-known serpentine pseudomorphs, so often described and figured by Tschermak and others in eruptive rocks. They are sometimes stained deep red by iron oxide, which occasions the above-mentioned blood-red spots.

The persistence of structure in this rock, in spite of the profoundest chemical changes, is remarkable. In one porphyritic specimen the groundmass is almost all carbonate, the mica has become quite colorless, and the olivine crystals are changed to a perfectly isotropic, colorless substance, enclosing the sharpest possible rhombohedra of dolomite; in fact none of the original components remain except the chromite, and yet the structure is just as sharp and characteristic as in the specimen above figured.

The geological occurrence of the Syracuse serpentine can unfortunately no longer be studied, as the exposure has been inaccessible for over forty years; still some evidence of its character may be derived from the testimony of observers and from a study of specimens. Mr. Wilkinson, in his letter above alluded to, says that an opening made only 50 feet away, *on the strike of this serpentine, passed entirely through gypsum.* The deposit is described as a horizontal bed between layers of porous dolomite, but it may have been intruded in this form between them as along the line of least resistance.

It is particularly mentioned by Vanuxem that the Syracuse serpentine has nowhere modified the surrounding limestone in a manner that would indicate that it was once in a molten state. Now, as is well-known, among all the igneous rocks, peridotite is the particular one which is *least* liable to produce contact metamorphism in the adjoining beds. Rosenbusch, in his most recent work, omits all mention of this subject in connection with peridotite, although he lays much weight upon it in connection with all the other plutonic rocks. Nevertheless, Mr. Diller has lately shown that the eruptive peridotites of Elliott Co., Ky., have altered to a slight degree, the shales through which they break; and I think that there is undoubted evidence that the Syracuse rock did the same. This alteration could not, however, be detected without the aid of the microscope. It is now impossible to examine the action of the mass as a whole, but certain specimens in my possession show plainly the effect of heat upon fragments of limestone which have been included in the serpentine mass.

If the serpentine of Syracuse were eruptive we should naturally expect to find the more granular variety near the center, and the porphyritic variety near the edge of the mass. No notes relating to such a distribution exist on any of Prof. Root's labels, but that such was the relative arrangement, is shown by inclusions of a very fine-grained, compact, gray limestone which are abundant in the porphyritic variety. Some specimens are mere limestone breccias with a serpentine cement. These inclusions are the "calcareous accretions"* of Vanuxem; and, though the line of contact between them and the serpentine is very sharp, they show an important modification consisting of the development in them of a greenish substance. This is most pronounced near the serpentine and fades away gradually as we go from it. The band is sometimes only a few millimeters wide and often has a zonal structure. One polished specimen shows the line of contact with the adjacent limestone (probably not an inclusion) and in this there are irregular

* His granitic and syenitic accretions may have been foreign inclusions brought up with the rock from far below the surface.

green bands running perpendicular to the line of contact across the entire surface. This green color is seen under the microscope to be due to the secondary development of a green mineral in a very finely divided state, which, to judge from its color, extinction angle and pleochroism, is amphibole, although it possesses no crystal form. More rarely there is some brownish substance resembling mica, but not in a well characterized form. Both of these are common contact minererals in limestones and have here undoubtedly been secondarily developed by heat.

The main points of evidence, therefore, that the serpentine at Syracuse was originally an igneous and intrusive rock, belonging to the family of peridotites, are as follows:

1st. The structure of the rock, which is such as is only known to be produced by crystallization from a molten magma.

2d. The existence of a more granular and a porphyritic modification, as is so often the case in eruptive dykes.

3d. The inclusion in the rock of fragments of the adjacent limestone and possibly of other rocks brought up from below.

4th. The indication that these limestone fragments have been modified by the action of heat.

5th. The fact, stated by Mr. Wilkinson, that 50 feet away from the exposure, on the strike of the rocks, only gypsum was encountered.

This evidence has been developed at such length, because aside from its bearing upon Dr. Hunt's theory of the origin of serpentine, this rock is interesting as being the only known instance of an igneous intrusion in the unaltered and undisturbed palæozoic strata of New York.

In conclusion it is worth while to notice the extremely close resemblance between the Syracuse rock and the peridotites of Carboniferous age which Mr. J. S. Diller of the U. S. Geological Survey, has recently described from Elliott Co., Ky.* These rocks are intrusive through Carboniferous strata and hence must be of as late origin as these, although they may be considerably younger. They contain fragments of the adjoining shale, which they have metamorphosed in a manner similar to that in which the dolomite inclusions have been changed by the Syracuse peridotite. Fragments of syenite and granulite were also found analogous to those granitic and syenitic aggregates mentioned by Vanuxem. In structure the two rocks present the closest possible similarity. The size and form of the large porphyritic olivine crystals appear to be identical in both; the groundmass of both also has the same appearance, containing

* "Science" for January 23, 1885, p. 65; this Journal, xxxii, p. 121, August 1886, and Bulletin of the U. S. Geological Survey, No. 38, the proof-sheets of which were kindly placed at the writer's disposal by Mr. Diller.

in each case, an abundance of opaque and transparent octahedral crystals. Nevertheless certain mineralogical differences are apparent. The pyrope with its alteration rim, described by Mr. Diller, is wanting in the Syracuse rock; ilmenite too, estimated to compose 2·2 per cent of the Kentucky peridotite, was not detected in the Syracuse occurrence. On the other hand, biotite and enstatite are much more important constituents in the latter than in the former. The little transparent crystals in the Kentucky peridotite are considered by Mr. Diller, as anatase (octahedrite) which has resulted from the alteration of the ilmenite. For reasons above stated, those in the Syracuse rock must, however, be regarded as perofskite, although their resemblance is so great as to suggest that they are the same mineral in both cases.

Petrographical Laboratory of Johns Hopkins University, Baltimore, April, 1887.

ART. XVIII.—*Note on the Genus Archeocyathus of Billings;* by CHARLES D. WALCOTT.

THE genus Archeocyathus was proposed by Mr. E. Billings, in a pamphlet entitled "Geological Survey of Canada: Sir W. E. Logan, Director. 'New Species of Lower Silurian Fossils;' by E. Billings, F.G.S., Paleontologist G.S.C. Montreal, 21st November, 1861."

A copy of this pamphlet was received by Professor Jules Marcou on December 15th, 1861.

In a copy of the pamphlet now before me the genus is described on page 3, and the characters are largely drawn from *A. Atlanticus*, the first species following the generic description on page 4. The second species is *A. Minganensis*, a form referred to the genus, *not* used as its type, and it was not illustrated. In 1865 Mr. Billings proposed the species *Archeocyathus profundus* (Pal. Foss., vol. i, p. 4), and placed it after the description of the genus, without mentioning that the genus was founded on *A. Atlanticus*, and, on p. 355, he gives *A. profundus* as the type, then *A. Minganensis;* and refers to *A. Atlanticus* as the third species of the genus. This has led the paleontologists, who have not seen the pamphlet of 1861, to consider *A. profundus* as the type of the genus Archeocyathus.

I found that *A. Atlanticus* belonged to one genus and *A. profundus* to a different and distinct genus; and as Mr. F. B. Meek had proposed the genus Ethmophyllum for a species generically identical with *A. profundus*, I referred the latter species to Ethmophyllum, as the type of a genus cannot be

taken from a species described four years after the genus is proposed, especially as the original type belongs to a different genus from that of the species taken as the type at a later date. Mr. Billings, in his original comparison of *A. Atlanticus* and *A. Minganensis*, says: "It may be that these two species should be placed in different genera," and repeats the remark in the reprint of 1865; but, in the latter, the name *A. Minganensis* is replaced by *A. profundus.*

In my remarks upon the genus Ethmophyllum (Bull. 30, U. S. Geol. Survey, p. 75), I called attention to the publication, in vol. ii of the Geology of Vermont, of the genus Archeocyathus. At that time I was not aware of the fact of the prior publication of the pamphlet by the Geological Survey of Canada, nor that the Geology of Vermont was issued in 1862 and not in 1861—the date on the title-page. I am indebted to Professor Jules Marcou for calling my attention to the existence of the pamphlet of 1861 and to the date of the publication of the Geology of Vermont, as 1862. It is noted, in the Geology of Vermont, that the descriptions were taken from a pamphlet sent by Mr. Billings, but not being able to obtain any trace of the pamphlet, as a publication at the time, I referred the original description to the Geology of Vermont, vol. ii.

I have written the above explanation, owing to having received a letter from a distinguished paleontologist, who questioned the propriety of using the genus Ethmophyllum for the generic type, so well illustrated by *Ethmophyllum Whitneyi* and *E. profundam.* I did not feel warranted when describing the genus in Bull. 30, U. S. Geol. Survey, in proposing a new genus for *Archeocyathus Atlanticus*, or in placing Ethmophyllum as a synonym of Archeocyathus; and since reading the original pamphlet of Mr. Billings, I am disposed to adhere to the views which I then held on this subject.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *On the Cause of Iridescence in Clouds;* by G. Johnstone Stoney.—When the sky is occupied by light cirro-cumulus cloud, an optical phenomenon of the most delicate beauty sometimes presents itself, in which the borders of the clouds and their lighter portions are suffused with soft shades of color like those of mother-of-pearl, among which lovely pinks and greens are the most conspicuous. Usually these colors are distributed in irregular patches, just as in mother-of-pearl; but occasionally they are seen to form round the denser patches of cloud a regular colored

fringe, in which the several tints are arranged in stripes following the sinuosities of the outline of the cloud.

I cannot find in any of the books an explanation of this beautiful spectacle, all the more pleasing because it generally presents itself in delightful summer weather. It is not mentioned in the part of Moigno's great *Répertoire d'Optique* which treats of meteorological optics, nor in any other work which I have consulted. It seems desirable, therefore, to make an attempt to search out what appears to be its explanation.

At the elevation in our atmosphere at which these delicate clouds are formed the temperature is too low, even in midsummer, for water to exist in the liquid state; and, accordingly, the attenuated vapor from which they were condensed passed at once into a solid form. They consist, in fact, of tiny crystals of ice, not of little drops of water. If the precipitation has been hasty, the crystals will, though all small, be of many sizes jumbled together, and in that case the beautiful optical phenomenon with which we are now dealing will not occur. But if the opposite conditions prevail (which they do on rare occasions), if the vapor had been evenly distributed, and if the precipitation took place slowly, then will the crystals in any one neighborhood be little ice-crystals of nearly the same form and size, and from one neighborhood to another they will differ chiefly in number and size, owing to the process having gone on longer or taken place somewhat faster, or through a greater depth, in some neighborhoods than others. This will give rise to the patched appearance of the clouds which prevails when this phenomenon presents itself. It also causes the tiny crystals, of which the cloud consists, to grow larger in some places than others.

Captain Scoresby, in his 'Account of the Arctic Regions,' gives the best description of snow-crystals formed at low temperatures with which I am acquainted. From his observations it appears—(*a*) that when formed at temperatures several degrees below the freezing-point, the crystals, whether simple or compound, are nearly all of symmetrical forms; (*b*) that thin tabular crystals are extremely numerous, consisting either of simple transverse slices of the fundamental hexagon, or, more frequently, of aggregations of these attached edgewise and lying in one plane; and (*c*) that, according as atmospheric conditions vary, one form of crystal or another largely preponderates. A fuller account of these most significant observations is given in the Appendix to this paper.

Let us then consider the crystals in any one neighborhood in the sky, where the conditions that prevail are such as to produce lamellar crystals of nearly the same thickness. The tabular plates are subsiding through the atmosphere—in fact falling towards the earth. And although their descent is very slow, owing to their minute size, the resistance of the air will act upon them as it does upon a falling feather; it will cause them, if disturbed, to oscillate before they settle into that horizontal position

which flat plates finally assume when falling through quiescent air. We shall presently consider what the conditions must be, in order that the crystals may be liable to be now and then disturbed from the horizontal position. If this occasionally happens, the crystals will keep fluttering, and at any one moment some of them will be turned so as to reflect a ray from the sun to the eye of the observer from the flat surface of the crystal which is next him. Now, if the conditions are such as to produce crystals which are plates with parallel faces, and as they are also transparent, part only of the sun's ray that reaches the front face of the crystal will be reflected from it: the rest will enter the crystal, and, falling on the parallel surface behind, a portion will be there reflected, and, passing out through the front face, will also reach the eye of the observer. These two portions of the ray—that reflected from the front face and that reflected from the back—are precisely in the condition in which they can interfere with one another, so as to produce the splendid colors with which we are familiar in soap-bubbles. If the crystals are of diverse thicknesses the colors from the individual crystals will be different, and the mixture of them all will produce merely white light; but if all are nearly of the same thickness, they will transmit the same color toward the observer, who will accordingly see this color in the part of the cloud occupied by these crystals. The color, will, of course, not be undiluted; for other crystals will send forward white light, and this, blended with the colored light, will produce delicate shades in cases where the corresponding colors of a soap-bubble would be vivid.

We have now only to explain how it happens that on very rare occasions the colors, instead of lying in irregular patches, form definite fringes round the borders of the cloudlets. The circumstances that give rise to this special form of the phenomenon appear to be the following:—While the cloud is in the process of growth (that is, so long as the precipitation of vapor into the crystalline state continues to take place) so long will the crystals keep augmenting. If, then, a cloudlet is in the process of formation, not only by the springing up of fresh crystals around, but also by the continued growth of the crystals within it, then will that patch of cloud consist of crystals which are largest in its central part, and gradually smaller as their situation approaches the outside. Here, then, are conditions which will produce one color round the margin of the cloud, and that color mixed with others, and so giving rise to other tints, farther in. In this way there comes into existence that iris-like border which is now and then seen.

The occasional upsetting of the crystals, which is required to keep them fluttering, may be produced in any of three ways. The cloudlets may have been formed from the blending together of two layers of air saturated at different temperatures, and moving with different velocities or in different directions. Where these currents intermix a certain amount of disturbance will pre-

vail, which, if sufficiently slight, would not much interfere with the regularity of the crystals, and might yet be sufficient to occasion little draughts, which would blow them about when formed. Or, if the colder layer is above, and if it is in a sufficient degree colder, there need not be any previous relative motion of the two layers; the inevitable convection-currents will suffice. Another, and probably the most frequent, cause for little breezes in the neighborhood of the cloudlets is, that when the cloudlets are formed they immediately absorb the heat of the sun in a way that the previously clear air had not done. If they absorb enough they will rise like feeble balloons, and slight return currents will travel downward round their margins, throwing all crystals in that situation into disorder.

I do not include among the causes which may agitate the crystals another cause which must produce excessively slight currents of air, namely, that arising from the subsidence of the cloudlets owing to their weight. The crystals will fall faster where in cloud masses than in the intervening portions where the cloud is thinner. But the subsidence itself is so slow, that any relative motions to which differences in the rate of subsidence can give rise are probably too feeble to produce an appreciable effect. Of course, in general, more than one of the above courses will concur; and it is the resultant of the effects which they would have separately produced that will be felt by the crystals.

If the precipitation had taken place so very evenly over the sky that there were no cloudlets formed, but only one uniform veil of haze, then the currents which would flutter the crystals may be so entirely absent that the little plates of crystals can fixedly assume the horizontal position which is natural to them. In this event the cloud will exhibit no iridescence, but, but instead of it, a vertical circle through the sun will present itself. This on some rare occasions is a feature of the phenomenon of parhelia.

It thus appears that the occasional iridescence of cirrus clouds is satisfactorily accounted for by the concurrence of conditions, each of which is known to have a real existence in Nature. . . .—*Phil. Mag.*, July, 1887.

2. *Note on some Experiments on the Viscosity of Ice;* by J. F. MAIN (Abstract).—The paper contains an account of some experiments on the continuous extension of bars of ice subjected to tension, made during the last winter in the Engadine. To eliminate the influence of regelation, the experiments have been carried on at such low temperatures as to preclude the possibility of any effect being produced by this cause. The highest temperatures during the experiments were —2·6° C. in Experiment I; —1·0° C. in Experiment II; and —0·5° C. in Experiment III. These maximum temperatures only obtained for a very short time on one or two days.

The bars were tested in a compound level testing machine with accurate knife edges, the load being a known weight of shot. The whole apparatus was enclosed in a double wood box. A delicate thermometer graduated to tenths of degrees, attached

inside the box, gave the temperature at any given time, and the range of variation of temperature was recorded by two maximum and minimum thermometers, fixed inside to the roof of the inner box. To obtain ice free from air, water was boiled and then frozen. It was then melted and again frozen in a mould. Some difficulty was found in holding the ice-bars in the testing machine. The mode which answered best was to freeze the ends of the ice bar into conical metal collars, which fitted the shackles of the machine. Extensions were measured by vernier callipers reading to one-fiftieth of a millimeter between marked points on the metal collars. To determine if any appreciable effect was due to distortion of the enlarged ends of the bars in the metal collars, pieces of paper were gummed on the ice, and the extensions also measured between fine pencil marks on these pieces of paper. It was found that nearly all the stretching observed in measuring between the metal collars was due to stretching of the bar of ice, and only a very small part to shearing action in the collars. In consequence of rapid evaporation from the surface of the ice bar, the stress with a fixed load on the lever increased from day to day.

Three experiments are given on bars initially about 234mm. in length, loaded to stresses of from 4·3 to 2·0 kilos. per square cm., and lasting from four to nine days.

The three experiments show that ice subjected to tension stretches continuously by amounts which depend on the temperature and the tensile stress. When the stress is great and the temperature not very low, there are extensions amounting to one per cent. of the length per day. So continuous and definite is the extension, that it can even be measured from hour to hour. These extensions took place at temperatures which preclude the possibility of melting and regelation.

The author hopes that on resuming the experiments next winter at St. Moritz, he may be able to determine more exactly the law of the extension. He has shown already that the extension increases continuously with all stresses above one kilo. per square cm., and at all temperatures between —6° C. and freezing. When ice is in a condition such that the point of a needle will cause a set of radiating fractures to pass from the point of contact in all directions, it stretches as certainly, though not by so great an amount, as when it will permit the passage through it of the same needle without showing flaw or scar.

In the first experiment there was a total extension of 11 mm. in nine days; in the second of 1·8 mm. in five days; in the third of 1·7 mm. in three days. If we assume the extension proportional to the time, there was a mean daily extension of 1·2 mm., 0·36 mm., and 0·56 mm. respectively. The stress in No. 1 was greater than in Nos. 2 and 3, and the temperature not so very low in the day, though low at night. In No. 3 there was a low stress, but comparatively high temperature.—*Proc. Roy. Soc.*, xlii, 331.

3. *Steam Calorimeter.*—A remarkable, simple and exact method of determining the specific heat of a solid has been perfected by

Bunsen. The process depends upon the condensation of steam upon the solid under examination, when the latter is immersed in steam. The difficulties of weighing the water of condensation have been completely obviated by suspending the substance in a small platinum basket, with fine meshes, in steam and weighing it without withdrawing it from the steam. The ingenious and simple apparatus by means of which this is accomplished is figured in the author's paper. The simple formula, in which all the quantities can be determined with great exactness is as follows:

$$G_\omega L = \delta_\kappa G_\kappa (t_1 - t) + \delta_\rho G_\rho (t_1 - t).$$

Where G_ω is the weight of the condensed water, L the latent heat of the steam at temperature t_1, G_κ the weight of the body, and t its temperature, δ_κ its specific heat, G_ρ the weight of the platinum basket, δ_ρ its specific heat (by suitable modification of the formula, the specific heat of a liquid can also be obtained).—*Ann. der Physik und Chemie*, No. 5, 1887, pp. 1–14. J. T.

4. *Electrical Resistance of Antimony and Cobalt in a Magnetic field.*—Dr. G. Faè experiments show that when antimony is brought into a magnetic field its electrical resistance increases both across and along the lines of magnetic force. Cobalt shows a diminution of resistance in a plane perpendicular to the line of force, and an increase in the direction parallel to them.—*Phil. Mag.*, June, 1887, p. 540. J. T.

5. *Effect of Electricity on Dust.*—R. Nahrwold shows that electrical charges escaping from fine points electrify the particles of dust or vapor in the air and not the air itself; also that glowing platinum wires throw off particles which make air a conductor (previously observed). The author believes that air and gases freed from dust can not be statically electrified. He also confirms the statement that negative electrical charges escape from points more readily than positive ones.—*Ann. der Physik und Chemie*, pp. 448–473, No. 7, 1887. J. T.

6. *The Hall Effect.*—A. Von Ettinghausen and W. Nernst have lately examined the Hall effect in different metals. They discovered that the effect is far greater in tellurium than in bismuth and they are led to think that the effect is connected with the thermo-electrical properties of the metals—the effect is least in tin. Taking the effect in tin as unity, the effect in the other metals examined are as follows:

Platinum	6
Copper	13
Gold	28
Silver	21
Palladium	29
Cobalt	115
Iron	285
Nickel	605
Carbon	4,400
Antimony	4,800
Bismuth	252,500
Tellurium	13,250,000

The sign of the effect is positive in cobalt, iron, steel, antimony, tellurium, lead, zinc, cadmium and negative in the other metals. —*Nature*, p. 185, June, 23, 1887. J. T.

7. *Practical Electricity;* a Laboratory and Lecture Course for first year Students of Electrical Engineering, based on the practical definitions of the Electrical Units. By W. E. AYRTON, F.R.S., etc. 16mo, pp. xvi, 516. London, 1887. Cassell & Company.—This book is intended, as the preface states, for first year students in electrical technology at the City and Guilds of London Central Institution at South Kensington. In arranging the order of subjects, the author has followed what appears to him to be "the natural as distinguished from the scholastic method of studying electricity." The first subject considered is current, then follows potential difference, and lastly resistance. The concluding chapters are devoted respectively to a discussion of Current generators, of Insulation, of Quantity and Capacity, of Commercial Ammeters and Voltmeters, and of Power and its measurement. The treatment of these subjects seems to be admirable. The book assumes only a moderate amount of previous training, and hence states what the student should know in quite an elementary way, but clearly, concisely, and logically. In speaking of current, for example, it says: "In reality we are sure neither of the direction of flow of an electric current nor whether there is any motion of anything at all;" and hence, "the statement that an electric current is flowing along a wire is only a short way of expressing the fact that the wire and the space around the wire are in a different state from that in which they are when no electric current is said to be flowing." The use of the letters P. D., potential difference, in place of the old E. M. F. is an important step of progress, and one which therefore should be generally adopted. All the values given are based upon the units adopted by the Paris Electrical Congress of 1884, though as they have not yet been legalized in this country or Great Britain, it is not easy to see why they are called "legal" units. The apparatus described is largely original and is well illustrated. A good feature which the author has adopted is to mount permanently on the same board the complete apparatus required for each experiment. Excellent examples by way of illustration are frequently introduced and the book closes with an appendix which considers Kirchhoff's laws of divided circuits and which gives several specimens of the instructions given to the students for performing the experiments. Professor Ayrton is well known as an able and indefatigable worker in the field of electrical science, pure as well as applied, and we think that the book before us will add to his reputation as being for its clearness, scientific accuracy, originality, and admirable method of arrangement the best book which has yet appeared on the subject of which it treats. G. F. B.

8. *On the Synthesis of Juglon.*—Several years ago yellow needle-shaped crystals were observed on the outer coating of walnuts gathered towards the close of June. These were examined by

Vogel and Reischauer, who found the same substance in the expressed juice, and gave to it the name nucine or juglon. BERNTHSON and SEMPER have now examined this substance and have proved it to be an α-hydroxy-α-naphthoquinone, $C_{10}H_5(O_2)''OH$. To complete the proof, these chemists have actually produced this natural product by synthesis from naphthalene. For this purpose they first prepared $\alpha_1\alpha_3$-dihydroxynaphthalene by Armstrong's method, by allowing a solution of naphthalene in carbon disulphide to drop into double the quantity of sulphuryl hydroxy-chloride. The sodium naphthalene-disulphate thus obtained was converted into dihydroxynaphthalene by fusion with potassium hydrate. To produce the juglon, this substance was treated in the cold with a chromic acid mixture. After twenty-four hours the brown precipitate was filtered off, washed, dried and extracted with ether. The ether was distilled off, the residue dissolved in chloroform and crystallized. The well known brown-red needles of juglon were obtained, having the odor of nutshells and producing violent sneezing when the dust was inhaled. The synthetic and the natural product were identical.—*Ber. Berl. Chem. Ges.*, xx, 934, April, 1887. G. F. B.

9. *A new basis for Chemistry: a Chemical Philosophy;* by THOMAS STERRY HUNT. 165 pp. 8vo. Boston, 1887 (S. E. Cassino).—This volume contains a connected summary of the author's views on chemical philosophy. The material is drawn to a large extent from his earlier papers ranging from 1848 down to the present time, but is here presented in systematic shape in chapters dealing with the nature of the chemical process, the genesis of the chemical elements, etc. Most of the papers referred to were published in this Journal; an article on chemical integration is given in this number.

II. GEOLOGY AND MINERALOGY.

1. *Geology of Long Island.*—Professor F. J. H. MERRILL, in his paper on the Geology of Long Island (Ann. N. Y. Acad., iii, 341, 1886, with a map of the island and a plate of sections), describes the general features of the island, the glacial drift, and the stratified beds of gravel, sand and clays, Quaternary, Tertiary or Cretaceous, which, excepting gneiss over a very small area, are the only deposits in sight. The greatest height according to the Coast Survey is 384 feet. In commencing his remarks on the drift, Mr. Merrill says: "Upham and others, in speaking of these ranges [the ranges of higher land, 100 to 384 in height] have called them moraines. If the word moraine is to be thus used" "it must be taken in a different sense from that accorded to it in most regions of glacial action." "Throughout most of Long Island" "the thickness of the drift marking the southern limit of glacial extension is very slight, and in some cases it is wanting; in these cases the term moraine would be synonymous with the southern limit of the continental glacier." The writer's conclusion after examinations of the coast regions and the West

Hills and other portions of the interior, and much effort to ascertain the limit on Long Island between the drift and the Tertiary beds beneath, coincides with that of Mr. Merrill. The height above the sea-level of the Tertiary (or Cretaceous) clay beds of the north shore of the island north of the West Hills of the central line, and their occurrence near the centre of the island in Bethpage at a level not far from a 100 feet, just south of the high "West Hills" lead naturally to the inference that boring would find the Tertiary at a height of at least 100 to 150 feet over much of the higher part of this land. The summit region of the West Hills and the long slopes either side have their cobble stones and some larger bowlders, along with the usual pebbly gravel, but nothing that would suggest by itself, as Mr. Merrill implies, a terminal moraine, or its limit. Still great bowlders occur along the shores, especially the northern, and on some other high elevations. Mr. Merrill states that one of gneiss on Shelter Island (in Peconic Bay) contains over 9000 cubic feet. The yellow pebbly gravels that cover the larger part of Long Island up to 100 feet and often higher, are stratified, and Mr. Merrill is disposed to make them equivalents of the pre-glacial yellow gravels of New Jersey. Whether this is the case, or whether they are Champlain deposits, the writer has not been able to decide.

The chief evidence of Cretaceous strata below Brooklyn at the west end of the island mentioned by Mr. Merrill is the discovery of an *Exogyra costata* with green sand adhering at a depth of 60 feet between Brooklyn and Flatlands, and an apparent stratigraphical relation to the Cretaceous of Staten Island and New Jersey. The author observes that the Cretaceous beds may extend as far eastward as Glen Cove, but that no satisfactory evidence has yet been found of their extending farther. The occurrence is mentioned of a tooth of *Carcharodon angustidens* or *megalodon* and recently of a small fossil leaf, in the clay beds of Little Neck; and this is the only paleontological evidence as to the Tertiary. The character of the clays, the general absence of lamination, the white and other colors, and the presence of much lignite, though generally in fragments as if transported, are evidence of Tertiary age, (if not of Cretaceous). But where the Tertiary ends and the Quaternary begins is a difficult problem unsolved.

The varying dip and flexures in the clay beds and the gravels associated with them, are described, and Mather's earlier work in this line referred to. This appearance of disturbance is well known to occur in all the islands east of Long Island to Martha's Vineyard. The flexures are described by Mr. Merrill as having a strike at right angles to the advancing glacier, and the conclusion thence drawn that they were produced by the push of the ice. The bays of northern Long Island, of remarkable depth (6 to 15 miles) for a coast of gravel deposits and clays, are regarded by the author as a result of excavations that were made by the same movement; and the high hills severally south of the bays are

spoken of as attendant and consequent results, sustaining by their positions this view of their origin. But the absence of bowlders from the bottoms of the valleys and their occurrence over the higher hill tops throughout the island, appear to the writer to be facts that bear against the above view. Moreover it seems to be hardly possible that the broad mass of the glacier, by pushing against the soft gravel and clay deposits could have been able to excavate such long localized channels, "walled in by high ridges" that are only ridges of unconsolidated material, making five such bays in a distance of only fifty miles. The wonder has been to the writer that the glacier left the soft deposits of so great depth—mostly over 100 feet, on the northern border of the island. May it not be that the glacier near its terminus had much less motion and therefore less abrading power than farther north, and that the depressions leading into and including these bays, and also the great Peconic Bay, are to a large extent results of erosion by running water before the glacier had deeply covered the land; perhaps from erosion by the rains that prevailed in the earlier part of the Glacial era, before the ice had reached so far south. The direction of movement in the glacier, judging from that over the higher part of western Connecticut was about S. 30°–35° E., while the trends of the five larger bays are, commencing with the western, (1) S. 11½° E., (2) S. 57° E., (3) S. 10° E., (4) S. 27° E., and (5) S. 26° E. for inner prolongation and S. 40°–50° E. for the main part of the bay.

The flexing of the clay beds may well have been accomplished by the advancing front of the glacier. The occurrence of lake depressions is well known to be another common feature in Long Island and the islands of similar geological features to the eastward; and it is a query whether the pressure of the overlying mass of ice added to that of the upper deposits may not in some places have forced the softened clay from beneath in a shoreward direction where was the only chance for escape, and thus have produced flexures and the basin-like depressions. For these clays of the bluffs are now constantly moving, from the pressure of the overlying gravel deposits aided by the outflow of the water of springs, thus causing fissurings and sinkings of the surface, great downslips of the gravel formations, the outflowing of the clays and thinning of the clay-beds, and making the coast region bad for the accurate study of the stratigraphy.

In these questionings of some of Mr. Merrill's conclusions, the writer has desired to suggest sources of doubt in order that they may be before future investigators. His own studies of Long Island have not been sufficient to settle the doubtful points. Borings in the soft material could be easily made and they would give positive facts, if not succeeding in tracing out in all cases the lower limit of the drift. J. D. D.

2. *Mount Taylor and the Zuñi Plateau;* by Capt. C. E. Dutton. 198 pp., roy. 8vo., with many illustrations. From the 6th Ann. Rep. of the Director of the U. S. Geol. Survey.—The

study of the Zuñi plateau in 1884, by Capt. Dutton, was essentially a continuation of his investigations of the plateau region of Utah and Colorado, the subjects of former memoirs. We take the following facts from the report. The plateau is situated in western New Mexico, between the parallels of 35° and 36° N., and the meridian of 108° and 109° W., near the Atlantic and Pacific railroad, having on the west side the Rio Puerco of the west, a branch of the Little Colorado, a southeastern tributary of the Colorado river, and to the eastward, the eastern Rio Puerco, a tributary of the Rio Grande. The prevailing formation about the region is Cretaceous—the most universal of Rocky mountain strata. Going westward from the eastern Puerco, the country becomes almost immediately that of the plateau region, which stretches west for 400 miles, with great uniformity in its geology and in the grandeur of its scenery. South of Fort Wingate rises the highest part of the Zuñi plateau. In the ascent the rocks change from the Cretaceous to the Jura-Trias. These Mesozoic rocks dip away from the interior of the plateau at a small angle, while the surrounding Cretaceous beds are horizontal. Over the plateau the rocks, after leaving the brightly colored Jura-Trias of the border, are the Permian, the Upper Carboniferous, and crystalline rocks, which are referred to the Archæan, these being brought to view by extensive denudation over the top of the swell.

The region differs strikingly from the plateau region of Utah, in the absence of all formations between the Upper Carboniferous and Archæan. A generalized section of the plateau (p. 137) includes Upper Carboniferous, 1200 ft. (of which 800 ft. are Lower Aubrey, and 400 ft. Upper); Permian, 450 ft.; Trias, 2050 ft. (1600 ft. of Lower Trias and 450 ft. of Wingate Sandstone); Jurassic? (the Zuñi sandstone), 1100 ft.; the Cretaceous, 2900 ft. (embracing 250 ft. of Dakota sandstone, 1200 ft. of Colorado, shales, 900 ft. of Lower Fox Hill, 550 ft. of Upper Fox Hill); Laramie group, 800 ft.; Wasatch sandstone, 1600 ft. The whole, the Wahsatch included, is believed to have covered the Zuñi region in the early Tertiary. A monoclinal uplift is described as occurring at Nutria, where the Cretaceous stands at an angle of 73°.

The high plateau northeast of the Zuñi mountains, north of the San José, has at top a broad area of igneous rocks, with Mount Taylor, a conical pile, toward its southern side, 11,389 feet high, as the great volcanic cone, standing 8,200 feet above the level of the plateau or mesa. Many small cones occur over the volcanic area marking the sites of former eruptions. The rock is mainly andesyte. The eruptions are referred to the Tertiary, probably the Middle Tertiary, the earliest "not much, if any older than the Miocene." More recent lavas, with cinder cones, occur around the eastern base of the Zuñi Plateau, the rocks of which are normal basalts.

In the statement of his general conclusions Captain Dutton

observes that the Mesozoic strata of the Great Basin are thickest to the westward, being 5,000 feet on its southwestern border; in the High Plateaus of Southern Utah, 3,000 feet; and in New Mexico, if the Zuñi sandstone be excluded, barely 2,000 feet. The Cretaceous is somewhat thinner in New Mexico than in Utah, and much thinner to the eastward in Texas. The facts are supposed to indicate a western origin for the great Mesozoic sediments.

Captain Dutton connects the upward flexing of the strata in the Zuñi plateau with the upward protrusion of a boss of underlying Archæan. He observes that in the "mountain platforms of Colorado the rising bosses of granite have not only flexed up the beds on the sides of the ranges, but have caught remnants of them within their disturbed tracts and carried them up with them, bending, warping and twisting them, shattering and faulting them."

In this Rocky mountain type of mountain structure, which includes as one of its varieties the vast monoclinal uplifts, the lifting force, Captain Dutton observes, acted vertically from beneath; and any appearances of a horizontal force are such as have resulted from the vertical movements. Archæan rocks hence are often the center or core of the mass. The fault-planes in the case of some of the monoclinal uplifts are believed to be vertical or nearly so, and therefore to accord with the theory of uplift by action from beneath.

Captain Dutton recognizes thus that the pitch of the fault-planes, in the case of the grander faults of a mountain region, bears strongly on the question as to the method of mountain-making concerned; prevailing low angles being as good evidence of lateral thrust as very high angles are of subvertical thrust; and no more important subject remains for investigation in the west than that relating to the dip of the planes in the grand monoclinal faults, about which little is yet positively known. The Appalachians of eastern America and the Juras and Alps in Europe are admitted to be wholly of different structure and mode of origin, lateral thrust having been somehow concerned in their formation. Captain Dutton's last sentence expresses in a word his own opinion, and that of most investigators in the region: "The mountains of the West have not been produced by horizontal compression, but by the action of some unknown forces which have pushed them up." J. D. D.

3. *Etudes sur les Bilobites et autres fossiles des Quartzites de la base du Système Silurique du Portugal*, par J. F. N. Delgado, Chef de la Section des Travaux Géologiques, Mem. de l'Acad. R. Sci. Lisbonne. 114 pp., 4to, with 42 plates. Lisbonne, 1886.—This memoir on the Bilobites, or the so-called fossil Algæ of the Lower Silurian, and especially those of the lowest quartzyte of the Silurian (Cambrian) of Portugal, by the distinguished head of the geological survey of Portugal, is a most forcible reply to the arguments and evidence presented by Mr. Nathorst of Sweden

in favor of the foot-print origin of the fossils. The author answers the arguments severally that are presented by Mr. Nathorst, while admitting the great interest of his investigation. But Mr. Delgado's most impressive argument is presented in the various figures of the remarkably fine specimens which he has obtained from the quartzyte of Portugal. The size, perfection, regularity of markings, and other characters, appear to place it beyond question that the larger forms at least are not mere tracks or markings on a bed of sand or mud. The many plates are phototypes of great perfection and beauty. The author reviews the literature of the subject, describes and figures the species of the Portugal quartzyte, some of them new, and cites, with remarks and figures, the published species of other regions.

4. *The Geology of England and Wales, with Notes on the Physical Features of the Country;* by H. B. Woodward, of the Geological Survey of England and Wales. 670 pp. 8vo. London, 1887. (G. Philip & Son).—This second edition of Mr. Woodward's Geology of England and Wales has received large additions in its preparation, and been brought down thereby to the year of publication. After a brief review of the subject of stratigraphy that of nomenclature is briefly considered, ending in the decision to use the old accepted terms in the present state of unsettled opinions. The Cambrian period is made to cover the whole of the Lower Silurian, as proposed by Sedgwick, in recognition of the fact that the most marked and general physical break in the formations between the top of the Paleozoic and the Archæan is that separating the Upper and Lower Silurian. The work then commences with the Archæan rocks and era, and presents the general and local facts, stratigraphical and geographical, for each period, with much detail and precision, and with a notice of the characteristic fossils. The reader derives from the work also a knowledge of the history of recent developments of the science, and numerous references are given to memoirs and other publications. The work has many illustrations, but none of fossils—the figures of which make so prominent a part of the large work on general geology by Etheridge and Seeley. It is accompanied by a large well-colored geological map. The series of geological formations is far more nearly complete in Great Britain than in any investigated area of equal extent over the globe; and a treatise on its local geology has, therefore, universal interest.

5. *Geologie von Bayern,* von Dr. K. N. von Gümbel. Erster Theil, Grundzuge der Geologie, Lieferung 4.—This 4th part of Dr. Gümbel's excellent work carries the volume to p. 960, and the descriptions of the geological formations from the Jura (p. 721) into the Pliocene. The page is large, the type rather small, so that a great amount of matter is presented; and the excellent illustrations are very numerous for each of the successive subdivisions. The profusion of figures will be appreciated from the single fact that those of the Pliocene alone represent more than a hundred species.

6. *Invertebrates from the Eocene of Mississippi and Alabama;* by OTTO MEYER, M.D. 6 pp. with one plate. (Proc. Acad. Nat. Sci., Phila., 1887).—Mr. Otto Meyer describes in this paper a number of new species of fossils found by himself, and gives good figures of them on the accompanying plate; and notes are added with figures also of some insufficiently known species.

7. *Contributions to Mineralogy;* by F. A. GENTH.—Dr. Genth has added another to his series of important papers upon American minerals. This contains a number of analyses of cassiterite and of tin ores from Zacatecas, Mexico; they are interesting as showing the presence of a large amount of foreign matter chiefly As_2O_5, Fe_2O_3 in the specimens of tin stone. A description is also given of the mimetite associated with the tin ore from the Mina del Diablo; it appears in pseudomorphous forms, well shown in a phototype plate, these in part resemble reticulated galena but are not all reconcilable with an original isometric form. Dr. Genth suggests that the original mineral may have been anglesite with which the measured angles agree pretty well. Two analyses (by H. F. Keller) are given of samples of vanadinite associated with descloizite from the Mammoth Gold Mine near Oracle, Pinal County, Arizona, and another by the author from Yavapai County.

The peculiar variety of descloizite from San Luis Potosi, called cupro-descloizite by Rammelsberg, ramirite by Velasquez, is analyzed anew with results identical with those of Penfield (this Journal, xxvi, 361); the remark is made that the tritochorite of Frenzel may probably have been the same mineral. Analyses are also given of hessite from Arizona, allanite from Chester County, Penn., and hisingerite from the Ducktown Mines, Tennessee.

8. *Silver in volcanic Ash.*—Professor MALLET has analyzed a specimen of volcanic ash collected on the Pacific coast in Ecuador, 120 miles west of Cotopaxi. The ash fell on July 23, 1885, and formed a deposit to the depth of several inches. The interesting feature in the composition of the material was the presence of a small amount of silver, probably as silver chloride; several experiments showed that silver was present to the extent of 1 part in 83,600 of ash. This is the first time that silver has been identified in material ejected from a volcano.—*Proc. Roy. Soc.*, xlii.

9. *Sixth Annual Report of the State Mineralogist of California.* Part I, 145 pp. 8vo. HENRY G. HANKS, State Mineralogist; Part II, 222 pp. WILLIAM IRELAN, JR., State Mineralogist.—These two parts are published separately and bear the dates of 1886, 1887 respectively. The first, by Mr. Hanks contains chapters on the building stones of California, the mineral springs, a table of altitudes, and finally a check list of California minerals. Part II by Mr. Irelan is largely devoted to the gold mines of the State with descriptions of methods of working, a summary of the U. S. Mining Laws, etc.

10. *Notes on the Minerals occurring in the neighborhood of Baltimore;* by GEORGE H. WILLIAMS. 18 pp. 8vo. Baltimore, 1887.—American Mineralogists will be interested in this excellent summary of the local mineralogy of Baltimore.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *List of Observatories and Astronomers.*—Mr. Lancaster, of the Brussels Observatory, has issued the second edition of his very useful *Liste Générale des Observatoires et des Astronomes, des Sociétés et des Revues Astronomiques;* Bruxelles, 1887, pp. 114. It contains the location and officers of the astronomical observatories, general statements about all existing astronomical societies, institutions and journals, a list of astronomers not connected with these institutions, and a list of astronomical instrument makers. The alphabetic index contains about 1000 names of persons. Over 240 public and private observatories are in the list, and 17 astronomical journals.

2. *Transactions of the Meriden Scientific Association*, vol ii, 64 pp. 8vo. 1885–1886. This volume contains a list of the birds of Meriden, by F. Platt, and a note by Dr. J. H. Chapin on the discovery by Mr. H. H. Kendrick at the quarries in the Triassic sandstone of Durham, Ct., of fossil plants, and among them, the fruit probably of a Cycad.

Report on the progress of the Adirondack Land Survey to the year 1886, with an historical sketch of the work and table of elevations, by Verplanck Colvin, Super't of Surveys. 344 pp. 8vo, with many plates and maps. Albany, 1886.

OBITUARY.

WILLIAM BOOTT, well known for his deep interest in botany, died in Boston on May 16. Mr. Boott was born in Boston on the 15th of June, 1805. He fitted for college at Exeter and entered Harvard University, but, owing to a weakness of the lungs, gave up his course and resided for a time in Europe, where he began the study of medicine. He did not complete his medical education, but, on his return to this country, engaged in business. During his long walks he became passionately fond of botany. Like his brother, Dr. Francis Boott, the celebrated Caricographer, he gave special attention to the grasses and sedges. For several years before his death he was an influential member of the committee appointed by the Overseers of Harvard College to visit the Botanic Garden and Herbarium, and his interest in these institutions continued to the very last. By his request, his collections and botanical library have been transferred to the University. Even during the last years of his life, when his strength began to fail, he was as ready as ever to give his aid and counsel to all younger botanists, and by them throughout the country his loss will be sincerely felt. G. L. G.

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Chas. D. Walcott,
U. S. Geological Survey.

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WITH PLATE I.

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In referring to the age of the deposits, while the old terms Miocene, Pliocene, etc., may be used for the sake of convenience, it must be clearly understood that, as at present defined, they are only of relative value and indicative at most of stratigraphical succession in a very limited sense. As determined by their invertebrate fauna, the Pliocene, for instance, of South Europe, is probably older than the strata called Pliocene in America, at all events, it is highly improbable that they represent synchronous geological epochs. The method of determining which name should be used for a particular division of the Tertiary, by taking percentages of the supposed extinct species, is, on the face of it, impracticable, illogical and misleading. Our knowledge of the Tertiary in America is still so fragmentary and imperfect as to render a sychronic sub-division of all the Post-Cretaceous strata impossible for the present.

Contemporaneous formations.

A large part of Southwestern Florida is covered with a sandy stratum which may average between two and five feet in thickness and has its upper surface more or less mixed with, or concealed by, the superficial humus. Although in the northern part of the State, ridges marking former boundaries of large lakes rise to more than two hundred feet above the sea, in the southern part the highest elevation is much less, and I have been informed that the rim separating Lake Okeechobee from the lowlands stretching to the Gulf of Mexico, was found by the Canal Company's engineers to be only some twenty feet high, a large part of which is composed of peaty vegetable matter. In the section afforded by the river below Fort Thompson and between it and the Gulf, nothing over fifteen feet in height was observed by us, though the land may rise somewhat higher, away from the river. A large part of the sand is derived from the wear of the limestone rocks which are webbed and clotted with bands, strings and irregular masses of silica, from the Miocene up, and over much of the State, though very irregularly distributed. But on the shores of the Gulf among the purer siliceous sand I observed that there are also particles of crystalline rocks foreign to the region and which occasionally are found in pieces weighing several ounces. The distribution of these particles and pebbles seems too general to permit of referring them to casual discharges of ballast by vessels.

The process of rock-formation is going on in a more obvious manner than would be expected along the Gulf shores of West Florida. There is a general opinion among the inhabitants, which was frequently expressed to me, in conversation, to the

effect that between Tampa and the Keys, coquina-rock is only to be found at one place, the mouth of Little Sarasota Pass. But this idea is certainly erroneous, as at every projecting point of the Keys along the Gulf shore which we visited, I found traces of this rock, though often not visible above water, and frequently composed more of sand-grains than of shell, so that it looks much like wet loaf sugar. It is doubtless being formed at many points along the Gulf shore, though in small quantities at each place, and not at all in the lagoons and harbors.

Another species of rock which strikes a northern observer as curious, is in process of formation by immense compact colonies of *Vermetus nigricans*, which raise the orifices of their minute blackish tubes to several inches above low water mark, and in some of the larger bays have formed extensive reefs. The animal has been supposed to be a worm, belonging among the *Serpulæ*, but I was able to determine its proper place by an examination of the soft parts. I have seen none of this rock in a strictly fossil state, though the species seems to occur in the Caloosahatchie Pliocene, but it is locally known as "worm-rock" and many of the "rocks" described by the natives of this region as cropping out along the shores, turn out on more particular enquiry to be of this kind.

There are three other sorts of rock of which the formation appears to be still going on. One is a more or less indurated sand, which was observed at Myers; also near St. James City on Pine Key; about a mile from the shore of Little Sarasota Bay, on South Creek, where it was found in the banks under the usual layer of sand; and close to the landing wharf at Sarasota, on Big Sarasota Bay. This rock is usually rather soft and contains recent land and a few recent marine shells. In other places, as at St. James City, it becomes extremely hard and compact, ringing under the hammer and almost destitute of fossils. A thin layer of it, from a mere film to three inches thick, marks the upper surface of the much older outcrop at White Beach, Little Sarasota Bay.

A second variety of rock is formed by springs containing iron in solution, which are numerous along the main shore as in both Sarasota Bays. This water consolidates the gravel, sand, shells, etc., over which it passes, into something resembling coquina, but in which the fragments of shell, etc., are united together by a cement of limonite. A spring near the estate of Judge Webb at Osprey, has thus affected a considerable part of what appears to be an Indian shell-heap; and among the shells, etc., in the rock may be detected fragments of pottery. Specimens showing this were brought home, and it is probable that the human remains discovered by Professor Heil-

prin in Sarasota Bay, which were replaced by a pseudomorph of limonite, are of similar origin and about equal age; although I was not able to visit the locality to verify this supposition.

The third variety I have not seen actually in formation, and it has not been observed on the western coast, but occurs along the upper St. John's River and about Lake Monroe, where I observed it in 1885. This is a sand rock in which each grain is coated with a pellicle of lime, giving the mass an oolitic appearance. In this rock, on Rock Island in Lake Monroe, Pourtalès and Wyman found the fossil remains of man which created so much excitement some years ago. The rock also contains recent land shells, but I observed no marine fossils. Rock of this character has been formed in Florida from the Miocene up, the phosphatic rock of Northern Florida is a variety of it, in which the limy envelope of the grains contains a certain amount of phosphoric acid.

Tertiary Rocks.

The blanket of sand, usually overgrown with scrub palmetto and cat-briars, which extends over so much of South Florida, renders the task of tracing the underlying strata very difficult. The sections afforded by the river banks and exposed on the sea shore are usually only a few feet above the water, and in the rainy season flooded, yet to these and to artesian borings the observer must go for his information. There are a number of rivers of reasonable size; but a wonderful absence of small streams, which may almost be said not to exist except during the rainy season. The soil and most of the underlying rocks are so porous that at other times all moisture sinks directly below the surface, or forms a marsh of greater or less extent. Clay is very rare and occurs in patches of small area, generally affording bones of extinct mammalia, saurians and tortoises. In northwestern Florida the oolitic phosphatic rock which overlies the Orbitoides limestone is compact enough to afford a bed for streams when it is continuous and forms the top rock. But as soon as the edge of this rock is reached the streams sink. Some notes on this formation, as reported on by Prof. E. Smith, Dr. Neill, and members of the U. S. Geol. Survey, will be found, greatly condensed, in the "Mineral Resources of the U. S." for 1885, under the head of Phosphates. I may add from my report of April, 1885, in regard to this rock, that "from a considerable area, between the localities where it is now found and the margin of the central depression or ancient lake basin of northern central Florida, it has been denuded, only fragments remaining scattered on the hilltops. The denuding agency made gullies or channels in which clay was deposited which, in its turn, has been more or less washed

away leaving only patches, generally in depressions but occasionally in short ridges. The appearance of the contained bones suggests that the animals were mired and then torn to pieces by predatory carnivora. Ashes and burnt clay were found under some of the bones at Hallowell's ranche but there was no evidence of any human agency in this. The fire was probably due to lightning, an every-day occurrence in Florida at the present time. The longitudinal splitting of the long bones sometimes observed, may often be the result of the penetration, and growth in the hollow of the bone, of roots, which might afterwards decay and leave no sign. I have observed roots penetrating the bones on several occasions." These bones are distributed over the State in many localities, especially in Alachua County.

The older rocks of course come out to the northward and along the central part of the peninsula, and the succession of the newer ones is toward the southern extreme end and the Atlantic and Gulf shores. The hypothetical southward extension of the Oligocene (sometimes taken as Eocene) on most recent geological maps now seems erroneous. It is without doubt represented as considerably too great.

Fossiliferous rocks have long been known to exist at Ballast Point, Hillsboro' Bay, near Tampa, where they were observed by Conrad more than 40 years ago. Recently Prof. Heilprin has examined them, referred them to the Miocene, and described a number of interesting species.

Here we find a state of things which is largely repeated in the younger strata to the southward. The rock rises but a few feet above the beach. Two layers may be distinguished, especially by their fossils, for the rocks are so broken up that the superposition of the newer layer here is less clear than I found it farther inland. The older rock is composed of a limestone, which in some places is so impregnated with silex as to form an almost pure flint; and at other spots retains its limy character, or is decomposed into a marl of peculiar tenacity. In many places the marl occurs in pockets surrounded by or covered with chert. In other spots it forms the greater part of the bank; but, however different in character, the chert and marl are merely parts of one stratum which has been subjected to different processes of mineralization in its different parts, and not two strata or rocks. In the chert the fossils, of which the rock is full, have disappeared, leaving cavities from which their forms may be reproduced by moulding in gutta percha. In the marl they have also disappeared but the smaller ones are represented by more or less perfect pseudomorphs of subtranslucent silex, reproducing every detail of the original shell. The larger ones, such as heads of coral, re-

tain their outward form, but are usually mere shells with an interior of botryoidal chalcedony, often of great beauty. The discovery here of *Ecphora quadricostata* by Dr. R. E. C. Stearns in 1869 (as pointed out in Science, vol. vi, p. 82, July 31, 1885) indicates the Miocene age of the rock; a suggestion which Heilprin has confirmed by his study of the silicified fossils collected here in 1885–86. The stratum affording these fossils is not limited to this locality. Conrad found it nine miles up the Hillsborough river which is fourteen miles or so to the northward and eastward from Ballast Point, and I am informed that the silicified fossils occur at various intermediate points along the bay shore. I found the same rock and fossils on Six Mile Creek at the head of navigation, near Orient station, about six miles to the eastward of Tampa, on the South Florida railway.

The fossils are chiefly marine, but there is a certain admixture of landshells which becomes more pronounced toward the top of the bed, indicating a gradual increase of the adjacent land area during the deposition of the bed. Finally, on the upper surface in some places nothing but landshells are found, showing that, at last, it became dry land at least in certain spots.

These landshells are all of extinct species allied more nearly to those of the West Indies than to the present fauna of the Southern States. A small bulimoid shell has been, I think incorrectly, referred to the Pacific genus *Partula*, which it somewhat resembles, as observed by Conrad forty years ago. But it is probably more nearly related to certain recent Bulimi of the northern Mexican and South American faunæ.

Above the stratum above described is a layer, from a foot and a half to ten feet thick, of limestone free from silex and pretty uniform in character. The fossils are mostly represented by external molds; but a few, and particularly an orbitolite described by Conrad, and probably identical with one now living at moderate depths on the Floridian coast, retain their shell structure. Some of the fossils in the lower stratum appear again in this one, but most of the species seem different and there is a notable absence of the large corals so abundant in the older layer. There are more species which seem to be represented in a living state in the present fauna.

This rock underlies the town of Tampa where wells are dug through it, and water obtained at a depth of ten feet or less. It is probable that the more compact cherty stratum underlies it here and forms a water table. The same rock occurs seven miles northeast of Tampa in wells, and also on land belonging to Mr. Lapenotière of Tampa (S.E¼ Sect. 14, T. 29 R.19), near Orient station. Its upper surface is about fourteen feet above Six Mile Creek near by, and about twenty-five feet above the

water in the harbor of Tampa at the railroad wharf, according to recent surveys. Its exact thickness here I was not able to determine. I was informed that the same rock occurred on the Manatee river above Braidentown and still farther to the south and west I observed it about one mile from Sarasota village, on the road from Braidentown, in the gulley of a small rivulet about half a mile from the shore of the bay.

This rock, which is evidently younger than the siliceous stratum, has been referred by Heilprin to the "Yorktown" epoch of Dana or Middle Miocene. There is an outcrop of rock at Bowley's Creek emptying into Sarasota Bay, about eight or nine miles N. W. of Sarasota, and about two miles from its mouth. This can only be reached at high water, and is then a foot or two below the surface. I visited it and succeeded in getting some fragments with prints of two species of *Pecten* and one of *Ostrea*, with traces of a *Spondylus*, all of which are represented either in other Miocene localities or in the outcrops at White Beach, about to be described. The rock was covered with quaternary beds of sand containing recent shells in a semi-fossil condition.

In the northwestern extreme of Little Sarasota Bay there is an outcrop of rock which at high water rises two or three feet above the water. It is a yellowish limestone much waterworn and covered in places with a thin layer of recent sand-rock. It contains distorted molds of many species which cannot be recognized, but in some places these molds have become filled with a pseudomorph in lime of the original shell. These pseudomorphs are gradually exposed by the action of the sea on the rock, and afforded about forty species of molluscan fossils, besides several corals and corallines. The rock did not show any foraminifera, though several of the species of shells are identical with those of the orbitolite stratum of Tampa.

Of the species obtained here eight appeared on a preliminary study to be new or peculiar to this locality; of the others, twelve seemed identical with species of the siliceous beds at Ballast Point, and four more with Miocene species from the island of Jamaica, West Indies, and other localities. Seventeen species, of which eight are supposed to be extinct, were subsequently found in the Caloosahatchie beds, and two are known from other Pliocene deposits. The other nine, with three not obtained on the Caloosahatchie, are believed to survive to the present day in adjacent waters.

While this association of species is probably only a small part of those which comprised the original White Beach fauna, the proportion of forms indicates that the stratum represented, is later than the Tampa Miocene, and that its fauna is transitional toward that of the Caloosahatchie deposits, which

probably followed it at no very great interval, geologically speaking.

The Caloosahatchie River, in the proper sense of the word, begins at the northeastern extreme of the long estuary which bears the name, some distance above the town of Myers.

The banks at first are extremely low and screened by thickets of mangroves which only disappear when the water becomes perfectly fresh. The land appears nearly level. As the river is ascended a close scrutiny shows that it cuts through a succession of gentle waves gradually increasing in height inland, whose crests would show a general parallelism with the direction of the peninsula of Florida, or transverse to the average course of the river. Near the head waters of the river these waves of elevation rise above the level of the river at low water, to a height of perhaps twelve feet at most, and their individual length from one trough to another may average about a quarter of a mile. Though insignificant as flexures they are interesting as showing that a lateral as well as a vertical thrust has attended the movements of the rocks in this part of the State, a fact which has been questioned.

The greatest elevation studied by us extends for several miles between the sites of the old forts Thompson and Deneaud. At the former point the canal from Lake Okeechobee enters the river, its bed being a compact rock which had to be blasted out. The succession of the strata is perfectly uniform, though the amount of their fossiliferous contents varies.

A section of the south bank, about two miles and a half below the end of the canal, gave eighteen inches humus and sand over the same depth of indurated yellow sand without fossils, below which are two feet of sandy marl with *Bulla striata*, *Venus cancellata*, and a multitude of *Planorbis* and *Physa;* then three feet of compacter marl with a great many marine fossils and comparatively few fresh-water shells, the deposit containing irregular nodules, lumps and strings of silicified material often extremely hard, and in which the fossils are often represented by mere molds. Below this, which is the chief fossiliferous stratum, lies a foot and a half of sand and marl with few fossils but many fragments, and worn siliceous fragments against which the water washes. This stratum in other places is consolidated to a tolerably compact rock, and the fossil bed above it to a flinty chert. The chert shows manifest indications of having been worn by the action of waves, and one of my specimens shows a boring bivalve still intact in its burrow in one of the protuberances of this layer. In other places fossil oyster-banks could be clearly seen, but nowhere any coral reefs, though isolated heads of coral were

not uncommon. The intermixture of fresh water shells and marine ones, is characteristic of the whole deposit, though the upper stratum contains proportionally many more fresh-water individuals. At the canal, and for some distance below, the beds above described are capped by a very hard Quaternary limestone full of silex and containing only fresh-water shells though occasional intercalated thin layers of marine shells, covered again by fresh water deposits, show that the sea was not far off, and that small alternations of level probably occurred. The same compact limestone, with the same species of *Planorbis*, etc., occurs near Hillsborough, by Tampa, and has been dredged in large masses from the channel by which the harbor of Tampa is entered. This shows a very wide extension of this deposit, the two localities being some ninety miles apart in a direct line.

The marls of the Caloosahatchie contain a large number of species, of which a fair proportion, perhaps one-tenth, are supposed to be extinct; many of the others are known only from deep water. How many of the so-called extinct ones, like *Amusium Mortoni*, will turn out to be still living when the deeper waters of the Floridian coast are thoroughly dredged remains to be seen. A number of the species appear to be more nearly related to shells known from the Asiatic or Californian coasts of the Pacific than to the shells of adjacent waters. But these apparent relations depend a good deal on our ignorance of what the deep waters of the Gulf really contain. In their curious partial silicification these beds afford an interesting parallel to those of Ballast Point, and show that similar chemical action has been going on since Miocene times on this coast.

The age of the Caloosahatchie beds is much the same as others which have been called Pliocene on our Eastern coast. The time has not yet arrived, nor is our knowledge of any part of our later Tertiaries sufficient to enable us to decide finally as to their chronologic relation to each other; except in the most tentative way. But without reference to their place in the system, the geological history of the Caloosahatchie marls is clearly stated in their structure.

The assemblage of species on the whole, in the principal stratum, is such as one might expect to find in water from twenty to fifty feet in depth, judging by what we know of living mollusks. Mixed with these are a certain number of shallow-water forms which may be supposed to have flourished as the water became shoal by elevation of the sea bottom. There were lagoons of fresh water and probably short streams emptying into the sea, and in time of flood sweeping their

fresh-water fauna out on to the shoals, where they died. Part of the bottom became elevated nearly to the surface, oyster banks were formed on it, and the compacter parts became water-worn. Large tortoises wandered there, and occasional mammoths. The absence of shells, like *Litorina* and *Nerita*, seems to indicate that the dry beaches were sandy rather than rocky. In the course of time elevation so shoaled the water that only species like *Venus cancellata* and others able to live between tide marks could remain. Finally the area became cut off almost entirely from the sea and occupied more or less by fresh water ponds in which the pond-snails multiplied in myriads. Drifting sand has buried these and in its turn has been covered with a thin coat of humus in which the pine, palmetto, and a host of scrubby plants make a fairly successful fight against the progress of civilization.

The history of Ballast Point seems to have been much the same in Miocene times, except that there the land seems to have risen sufficiently to enable true air-breathing landsnails to flourish. On the Caloosahatchie they are extremely rare, only one or two specimens having turned up among thousands of fresh-water snails. On the other hand, if Ballast Point rose higher, it was afterward depressed lower, so that several feet of marine orbitolite rock could be formed over it. On the Caloosahatchie the thickness of the marine strata over layers of the fresh water limestone did not exceed six inches.

As it may be supposed that the admixture of fresh water forms with the marine forms has been due to mechanical mixture after fossilization, which in certain places where the marl is penetrated by roots from above, might have occurred, I will add in concluding that the same mixture occurs in the interior of the most flinty chert bowlders. It is curiously paralleled by the mixture I have found in shells collected by the U. S. Fish Commission, in some of the inner lagoons of the Bahamas, where a similar series of geological changes may be supposed to be at this moment in progress. Among the fresh water species is a large *Cyrenella*, a genus recently found by Hemphill in a living state in a South Florida marsh. It has not been before known from the United States, and was originally described from Senegal.

No coral rock or coral reef formation was anywhere observed. The coral-formation observed by Agassiz in the region in the Keys, must be of very limited scope, as it has not been reported from the mainland of Florida by any modern geologist. That the peninsula could not have been formed on the Agassizian hypothesis was pointed out by me in 1882. (Saturday lectures, No. 7, p. 18; Washington, Judd and Detweiler, 1882.)

ART. XX.—*Notes on the Deposition of Scorodite from Arsenical Waters in the Yellowstone National Park;* by ARNOLD HAGUE, of the U. S. Geological Survey.

SCORODITE, although a comparatively rare mineral, is usually found associated with arsenopyrite in several widely separated parts of the world. It occurs in minute orthorhombic crystals in many well-known mining regions and is frequently observed coating crystals of quartz. Hermann mentions an amorphous scorodite from Nertschinsk, Siberia, with nearly the theoretical composition. Quite recently Professor A. H. Chester* has reported its occurrence in the Horn Silver Mine, Utah, where it is observed in thin crystalline crusts and amorphous layers. Crystals of artificially prepared scorodite have been produced by Verneuil and Bourgeois† by submitting metallic iron to the action of arsenic acid in sealed tubes at high temperatures. So far as I know, however, its occurrence as a deposition from thermal mineral springs has never before been noticed.

Scorodite is found in a number of localities in the Yellowstone Park as an incrustation deposited from the waters of several hot springs and geysers. The best occurrence, although the locality is one difficult of access, is at the Joseph's Coat Springs on Broad Creek, east of the Grand Cañon. This group of springs is situated along both sides of the stream bed between rhyolite ridges which rise abruptly for two or three hundred feet. Solfataric action has completely decomposed the rhyolite into smooth, rounded slopes of soft earthy material unsurpassed in beauty of color by any other locality in the Park; orange, yellow, vermilion and white are interblended in a most striking manner. A hundred narrow vents deposit crystals of yellow sulphur far too delicate for transportation. Added to this coloring are the deep greens, reds and yellows derived from the algeous growths lining the hot water channels running off from the numerous springs. Mineral and vegetable colors vie with each other in brilliancy.

On the west side, about 100 feet from the stream and 10 feet above the water, is situated a boiling pool which at the time of my visit, although not seen in action, I regarded as an active geyser. The following accurate description is taken from the note-book of Mr. Walter Weed who accompanied me to the locality: "The water is perfectly clear, deep blue in color, sulphurous in odor, and in constant agitation, bulging and boiling vigorously for about a foot above the level of the pool. The basin measures 10 by 12 feet and is edged and rimmed in by a curious yellow deposit with the hollows and

* This Journal, April, 1887. † Comptes Rendus, vol. xc, 1880.

spaces filled with a deposit of a brilliant green color. The steam is strongly sulphurous and is emitted in large volumes. The overflow is inconsiderable and runs towards the creek in a shallow channel which, near the spring, is lined with the same green coating."

Like all other springs of the group this one issues through fissures in the altered rhyolite, which, around the spring, is everywhere coated with siliceous sinter or geyserite derived directly from the hot waters. Deposited upon the sinter and intermixed with it, occurs the green coating. It lines the basin for about a foot or wherever the spray from the agitated waters falls upon the sides. Analysis shows this mineral to be scorodite, a hydrous arsenate of iron. The layers vary from a mere coating up to an eighth of an inch in thickness. Frequently the cavities and druses in the sinter are filled with scorodite and occasionally it forms nodular masses from a quarter to a half an inch in diameter. Wherever observed it occurs as an amorphous deposit, and when pure, leek green in color. Nitric and sulphuric acids apparently have no action upon the mineral but it is readily attacked by hydrochloric acid.

An analysis made by Mr. J. Edward Whitfield in the chemical laboratory of the Geological Survey, after neglecting a trace of sulphuric acid and a small amount of silica from which it was impossible to free the mineral, shows a nearly pure scorodite, closely agreeing with the theoretical composition. The result of the analysis is as follows:

Fe_2O_3	34·94
As_2O_5	48·79
H_2O	16·27
Total	100·00

Other localities for scorodite are Chrome Springs, at the base of Crater Hills, and one or two places in the Norris Basin. At the Constant Geyser in Norris Basin the water is thrown out two or three times a minute to a height varying from 10 to 20 feet. Around the vents the sinter deposits are finely laminated and show incrustations with greenish tints. Upon breaking off a piece of the sinter and examining a cross-section, thin layers and irregular deposits of scorodite may be observed. The scorodite is already partially altered to limonite and the sinter and pure mineral are more or less discolored by the oxide of iron. It is difficult to obtain a sufficient amount for analysis free from admixture of geyserite and iron oxide. A specimen from the Constant Geyser carrying much silica, yielded Mr. Whitfield as follows:

SiO_2	49·83
Al_2O_3	4·74
Fe_2O_3	18·00
As_2O_5	17·37
H_2O	10·62
Total	100·56

The scorodite, as it is found deposited from these thermal waters, is evidently a very unstable mineral and unless under favorable conditions for its preservation slowly undergoes oxidation, leaving an ochreous material carrying varying amounts of arsenic acid. Alteration into limonite readily occurs and the latter on exposure slowly disintegrates and is mechanically carried away by the action of the running water. Although pure scorodite is only sparingly preserved at a few localities in geyser basins, its identity with the well determined species from Joseph's Coat Springs is clearly made out, as it is easily recognized by the characteristic green color in strong contrast with the white geyserite and the yellow and red oxides of iron.

It may be well to add here that the vegetable green derived from the algeous growths found in nearly all the thermal waters of the Park is not to be mistaken for the mineral green of scorodite. The former is abundant in all hot spring areas, while the latter, a comparatively rare mineral, is obtained only in small quantities after careful search.

During the progress of the work of the Geological Survey in the Yellowstone Park, I have had collected a large number of samples of the thermal waters from the most interesting geysers and hot springs. These have since been subjected to searching analyses by Dr. F. A. Gooch and Mr. J. Edward Whitfield in the chemical laboratory of the Survey and their results which are of great interest will be published at an early date.

Unfortunately no sample of the water from Joseph's Coat Spring was obtained, but a careful analysis was made of the water from the Constant Geyser. This water was collected September 13, 1885; temperature 198° Fahr., the boiling point at this altitude; reaction slightly acid; specific gravity 1·0011.

For the purpose of comparison there is added here the analysis of the water from Old Faithful geyser in the Upper Geyser Basin. Date of collection, September 1, 1884; reaction, alkaline; specific gravity, 1·00096.

The analyses yielded as follows:

	Constant Geyser. Grams per kilogram of water.	Constant Geyser. Per cent of total material in solution.	Old Faithful Geyser. Grams per kilogram of water.	Old Faithful Geyser. Per cent of total material in solution.
Silica	0·4685	28·88	0·3828	27·52
Sulph. acid	0·0923	5·69	0·0152	1·09
Carbonic acid	0·0155	·95	0·0894	6·43
Boracic acid	0·0317	1·95	0·0148	1·07
Arsenious acid	0·0018	·11	0·0021	·15
Chlorine	0·5740	35·39	0·4391	31·57
Bromine	trace	-- --	0·0034	·25
Hydr. sulph.	none	-- --	0·0002	·01
Oxygen (basic)	0·0185	1·14	0·0419	3·02
Iron	trace	-- --	trace	-- --
Aluminium	0·0048	·29	0·0009	·06
Calcium	0·0146	·90	0·0015	·11
Magnesium	0·0018	·11	0·0006	·04
Potassium	0·0745	4·60	0·0267	1·92
Sodium	0·3190	19·67	0·3666	26·36
Lithium	0·0030	·19	0·0056	·40
Ammonium	0·00127	·08	0·00001	-- --
Hydr. (HCl)	0·0008	·05	---- -	-- --
Manganese		-- --	trace	-- --
Calcium		-- --	trace	-- --
Rubidium		-- --	trace	-- --
Total	1·62207	100·00	1·39081	100·00
Albuminoid ammonia,		none		0·00002

Thermal waters from the Upper, Lower and Norris Geyser Basins do not differ essentially in their ultimate mineral constituents but show considerable variation in the relative amounts of the salts present. All the waters from the geysers which have been subjected to chemical analysis carry arsenic, the quantity present, according to Gooch and Whitfield, varying from ·02 to ·25 per cent of the mineral matter in solution. That the arsenic of the scorodite is derived from the thermal waters is beyond question, and in my opinion, it is supplied to the waters by the action of superheated steam upon the rhyolite lavas which form the great mass of volcanic rocks of the Park plateau.

While arsenic has been determined in nearly all these waters in no instance has the presence of even a trace of deleterious metal been detected. Arsenical waters of sufficient strength and suitable for medicinal purposes are of rare occurrence. In the United States an undetermined trace of arsenic is reported in the Orkney, Rockbridge Alum, and Roanoke Red Sulphur Springs in Virginia,* and Dr. A. C. Peale informs me that so-

* Mineral Springs in the United States; Dr. A. C. Peale. Bull. 32, U. S. Geol. Surv., p. 64.

dium arseniate has been mentioned recently as occurring in a mineral water in Asche County, North Carolina.

Hygeia Spring, which supplies the bath houses at the hotel in the Lower Geyser Basin, is an alkaline siliceous water carrying ·3 of a grain of sodium arseniate to the gallon. In the amount of sodium arseniate held in solution the Yellowstone Park waters fall below the celebrated arsenical springs of La Bourboule in the volcanic region of the Auvergne, which within recent years have acquired a well deserved reputation for their alterative properties in skin diseases. While the Yellowstone Park waters are somewhat less rich in arsenic than those of La Bourboule they must greatly surpass the latter in their enormous overflow. The entire supply from the springs of La Bourboule amounts to 1500 gallons per minute. During the past season the cauldron of Excelsior Geyser in Midway Basin alone poured into the Firehole river, according to the most accurate measurements which could be made, no less than 4400 gallons of boiling water per minute. According to the analysis of the sample collected August 25, 1884, the water of this geyser contained .19 grains per gallon of sodium arseniate. As yet we know very little about the remedial properties of the Yellowstone waters. At no distant day experience may show that they are decidedly efficacious in external applications and under proper medical guidance may take high rank as arsenical waters for the cure of certain forms of nervous affections and cutaneous eruptions.

ART. XXI.—*The Effect of Magnetization on the Viscosity and the Rigidity of Iron and of Steel;* by C. BARUS.

MR. HERBERT TOMLINSON* has recently communicated results on the changes of viscosity and of elasticity produced by magnetizing iron. As both classes of data are obtained by the vibration method, it seems not undesirable to attempt to verify them by some static method, and the one described in my last paper† is so easily applicable that I have made use of it. My original purpose was to confine the investigation to measurements of viscosity; but I found in the course of the work that the incidental data on the rigidity of iron and steel could be grouped together. Taken collectively in this way, they led to inferences which the well-known and comprehensive researches

* Tomlinson: Beiblätter No. 3, p. 176, 1887; original in Proc. Roy. Soc., xl, p. 447, 1886, is unfortunately not at my disposal.

† This Journal, xxxiv, pp. 1 to 4, 1887. In equation (1), p. 1, of this article ψ is obviously to be replaced by $d\,\psi$.

of Wiedemann* insufficiently emphasize. I refer to the effect of magnetization on the rigidity of iron and steel, as modified by the dimensions of the metal temporarily strained. I shall show that the increment of rigidity due to magnetization increases at an accelerated rate as the soft, temporarily twisted wire becomes more nearly filimentary. Now, since the said increment is *independent* of the sign of the current in the helix, and moreover increases with the current intensity in a way which I have found not seriously irregular, it seems profitable to attempt to utilize this principle for the construction of electric dynamometers.† This is the point of view from which much of the present paper has been written. It also contains a series of results on the rigidity of magnetized steel temporarily strained and varying in temper from extreme hard to extreme soft.

Viscosity of Magnetized Steel and Iron.

Apparatus and method.—To make the present measurements it is merely necessary to replace the heating apparatus described in the former paper by an appropriate helix. The two wires to be examined are in the same vertical line, separated by a rigid piece of brass which carries the index mirror. Any desirable rate of twist may be imparted by rotating and then fastening either the upper or the lower end of the system. If both ends be rotated symmetrically in opposite directions, the mirror remains stationary. In this way any reasonable amount of twist may be stored without moving the image of the scale out of the field of the telescope.

The wires of the system were identical as regards length, diameter, and composition; and the arrangement adopted was such that at any time the upper wire might be under the influence of a powerful magnetic field. The helix used for this purpose consisted of ten layers of 230 turns each, doubly wound in such a way as to form two independent partial helices of 115 turns of wire for each layer. For the same current the fields of these partial helices were identical; by connecting them, either differentially or in series, the field obtained was either zero or the maximum for the given conditions. The length of the helix being 20^{cm}, its internal radius $1{\cdot}25^{cm}$, its external radius $2{\cdot}07^{cm}$, the magnetizing force at the center proves to be 1425 c. g. s. units of intensity per c. g. s. unit of current or 142·5

* Wiedemann: Pogg. Ann., ciii, p. 571, 1858; ibid., cvi, p. 161, 1859; Galvanismus, 3d ed., 1883, III, p. 683–698. Less closely allied researches on the effect of magnetization on torsion, etc., are due to Matteuci: C. R., p. 301, 1847, and to Wertheim: C. R., xxxv, p. 702, 1852, as well as to Wiedemann (l. c.), and more lately to Ewing (Proc. Roy. Soc., No. 228, p. 117, 1883).

† Cf. page 177.

$(g^{\frac{1}{2}}/c^{\frac{1}{2}}s)$ per Ampère. Current was obtained from five flat Grove cells, in mean intensity of about one Ampère. Hence the iron wires were probably not far from saturation, supposing that a field of 140 c. g. s. units of intensity is sufficient to magnetically saturate soft iron.

Without elaborate precautions it is impossible to produce a strong field for great lengths of time in this way, without perceptibly heating the helix. This introduces a serious error, for the viscous detorsion actually observed is due to a heat effect superimposed on a magnetic effect, both of which are of the same order of minuteness. By using a helix like the one above, in which current may be passed through the two partial coils in the same or in opposite directions, the full heat effect may be observed either with or without the magnetic effect. For when the coils are joined differentially the field produced is zero, whereas the heat generated in the helix is (cæt. par.) not changed in amount. This is the way in which I endeavored to eliminate the temperature discrepancy.

It is difficult to find two wires which are absolutely identical; after softening some parts of a wire yield more easily to stress than other parts. It is not until the less rigid parts have been stiffened by receiving permanent set that the rate of twist temporarily stored is the same throughout the length of the wire. All viscous motion which is due to differences in the mechanical or chemical properties of the metals may be detected by allowing series of observations for open circuit to alternate with similar series for closed circuit.

Results.—Table 1 contains results as obtained with steel annealed about midway between soft and hard. Here t is the temperature of the helix and of the upper wire, t' the temperature of the lower wire, l and ρ the length and radius of each. φ denotes the amount of viscous detorsion per centimeter per wire (i. e., per two centimeters of the system), in radians at the time h in hours; τ denotes the rate of twist in degrees imparted to the system at the unmagnetic end. If φ increases or decreases according as the sign of the twist is positive or negative, then the unmagnetic wire is of greater viscosity than the magnetic wire; and vice versa. Intervals of observation corresponding to open and closed circuits are appropriately indicated. Whenever the circuit is closed differentially in the helix so as to produce a zero magnetic field, this is also stated. φ is correct to 3 or 4 units of the last place.

The three parts of this table show that the viscous differences in question are invariably minute. In part first the originally less viscous lower wire becomes perceptibly more viscous when the circuit is closed around the upper wire. The apparent

effect of magnetization is here a decrement of viscosity. In the second part the wires for open circuit are equally viscous; for closed circuit the results are the same as in part first both as regards sign and amount. The apparent effect of magnetization is again a decrement of viscosity. Part third, finally, contains the interpretation of these results: it is seen that results of the same magnitude and character are obtained when the magnetic field due to the helix (other effects remaining the same) is zero. The viscous effects here observed are therefore wholly due to temperature, and it may be safely inferred that magnetized and unmagnetized steel differ in viscosity by an amount less than is produced by 5° difference of temperature.

TABLE 1.

Viscosity of steel, annealed 360°. $l=30^{cm}$; $2\rho=0{\cdot}083^{cm}$; $t'=20°$.

h	$\phi\times10^6$	t	Remarks.	h	$\phi\times10^6$	t	Remarks.
hours.	radians.	°C.		hours.	radians.	°C.	
0·00	− 0	--	Circuit open. $\tau=+6°$.	1·10	−21	--	Circuit closed. $\tau=-6°$.
2·67	−33	--		1·12	−10	19	
4·33	−35	--		1·40	−23	23	
24·00	−50	--		1·67	−23	25	
25·42	−50	--		1·92	−34	27	
25·60	−35	--	Circuit closed. $\tau=+6°$.	2·08	−38	--	
25·67	−15	--		2·40	−42	28	
25·83	− 3	--		2·80	−49	29	
26·00	+ 7	--		0·00	− 0	17	Circuit closed; field zero. $\tau=-6°$.
26·25	+10	--		0·18	−30	21	
26·75	+15	--		0·43	−46	26	
0·00	− 0	--	Circ't open. $\tau=-6°$.	0·60	−53	28	
1·00	− 3	--		0·85	−58	29	
				1·00	−63	30	
				4·52	− 7	--	Circ't open. $\tau=-6°$.
				23·25	−17	--	

Inasmuch as the steel wire of table 1st is permanently a magnet after the first induction, sharper results may be looked for in experimenting with iron. As regards viscosity, iron is less susceptible to the influence of temperature than either annealed steel or even soft steel; it is more magnetically permeable and it loses its magnetization completely when slightly jarred in a zero field.

Table 2 contains results for soft iron. The arrangement being identical in plan with table 1.

In the first part of table 2, φ increases whenever both wires are unmagnetic and decreases at a gradually diminishing rate whenever the upper wire is magnetic. The apparent effect of magnetization is therefore a diminution of viscosity, a result in accordance with the inferences from table 1. To interpret this apparent result the second part of table 2 is available. It

shows that when the current is passed through the helix differentially, φ increases at the same rate as before, notwithstanding the fact that the field is now zero. Hence the amount of viscous detorsion observed is a temperature discrepancy and no viscous effect due to magnetization is discernible.

TABLE 2.

Viscosity of magnetized iron. Rods Nos. 7, 8, annealed soft. $l=30^{cm}$; $2\rho=0{\cdot}110^{cm}$; $t'=20°$; $\tau=-3{\cdot}6°$.

h	$\phi\times10^6$	t	Circuit.	h	$\phi\times10^6$	t	Circuit.
0·00	0	--	Open.	3·48	+15	26	
0·57	−3	--		3·68	+4	30	Closed.
0·58	+65	--		4·05	−5	34	
0·92	30	33	Closed.	4·05	−72	34	Open.
1·23	8	34		4·47	−62	29	
1·23	−58	33	Open.	4·52	−55	--	
1·80	−53	28		4·75	−65	32	Closed differentially; magnetic; field zero.
1·85	+18	--		4·92	−63	33	
2·00	+10	29	Closed.	5·07	−70	34	
2·17	0	33		5·38	−73	--	
2·48	−3	34		5·56	−73	--	Open.
2·50	−71	34		22·30	−50	--	
2·97	−60	29	Open.				
3·47	−52	26					

In table 3, I give similar results with a thinner wire.

TABLE 3.

Viscosity of magnetized iron. $l=30^{cm}$; $2\rho=0{\cdot}083^{cm}$; $t'=20°$; $\tau=-3°$.

h	$\phi\times10^6$	t	Circuit.	h	$\phi\times10^6$	t	Circuit.
0·00	0	--	Open.	5·13	310	--	
0·38	80	--		5·57	328	25	Open.
0·42	189	21		23·00	545	18	
0·50	195	21		23·10	653	--	
0·75	220	26	Closed.	23·33	645	--	
1·05	245	29		23·67	643	28	Closed.
1·38	265	30		24·00	645	30	
1·42	161	30		24·05	538	30	
1·68	183	28		24·42	550	26	Open.
1·95	203	25	Open.	24·95	560	23	
2·17	218	23		24·97	670	--	
2·18	328	24		25·33	660	28	Closed.
2·48	334	27		26·17	668	32	
2·88	348	30	Closed.	26·20	561	--	Open.
3·23	360	32		27·12	580	23	
3·25	255	--		27·27	690	--	Closed.
3·50	270	--	Open.	28·28	685	31	
4·17	298	--		28·35	580	--	Open.
4·20	407	--		48·00	740	--	
4·67	410	28	Closed.				
5·08	420	30					

In these results the thermal and magnetic effects are superimposed on the continuous viscous motion due to inequalities in the wires, the upper wire being more viscous than the lower wire. In every case, however, this normal viscous detorsion is perceptibly retarded whenever the upper wire is magnetized. It follows conformably with the above results that the viscosity of iron is apparently diminished by magnetization; that the amount of this diminution is no larger than is quite in keeping with the heating effects due to the passage of current through the helix. My results therefore fail to give any satisfactory proof that magnetized and unmagnetized iron differ in viscosity by more than the equivalent of one or two degrees centigrade, at ordinary temperatures.

I am far from wishing to assert, however, that Tomlinson's results are temperature phenomena. It is possible that the marked tendency of soft iron to assume permanent set, and consequently the relatively large viscous motion immediately after strain is imparted, makes the vibration method particularly sensitive in registering the viscous effect of magnetizing iron.* But by using static methods and observing in the interval of *gradual* or *purely viscous* deformation, no satisfactory evidence of such an effect is discernible. Moreover, magnetization changes the rigidity of iron and therefore necessarily jars a twisted wire. There result such changes of viscosity as are produced by any sudden vibratory disturbance; changes which of course are purely mechanical, but which obscure the direct result of magnetic induction beyond recognition.

RIGIDITY OF MAGNETIZED IRON AND STEEL.

Iron.—The effect of longitudinal magnetization on iron or steel twisted within the elastic limits is marked detorsion, increasing in amount with the intensity of magnetic field, increasing also with the rate of twist, at a retarded rate in both instances, toward a maximum. If the sense of the magnetization be reversed (i. e., if the helix current be changed in direction) the amount of detorsion is in general unchanged.†

In tables 1, 2, 3, discontinuous but perfectly regular variation of φ, on passing from unmagnetized to magnetized iron or steel are strikingly apparent. Table 4 contains special results for large rates of twist (τ), and has been drawn up to exhibit the independence of φ of any possible irregularities in the position of the helix as well as the change of sign of φ with the sign of τ. The table shows also that the sign of φ is

* Cf., moreover, Wiedemann's remarks on the vibration method, Wied. Ann., vi, 485, 1879.

† The above phenomena have been elaborately discussed by Wiedemann (Galvanismus, pp. 683–698).

reversed when the helix is passed from the upper to the lower wire. It follows, therefore, that φ is not influenced by errors which in my apparatus might result from the increase of length due to magnetization. In other words, in the mechanism adopted magnetic elongation has no rotational effect. l and ρ denote length and radius each in centimeters. τ is in degrees, φ in radians, as above.

TABLE 4.

Showing the effect of sign of twist and of position of helix.

REMARKS.	No.	τ	$\phi\times 10^6$
Helix symmetrically on upper wire	17, 18	+6	−130
	$2\rho=0{\cdot}053^{cm}$	−4·5	+133
	$l=30^{cm}$	+6	−139
Helix symmetrically, on *upper* wire	19, 20	−3·0	+93
" +eccentrically, " "	$2\rho=0{\cdot}083^{cm}$	−3·0	95
" −eccentrically, " "	$l=30^{cm}$	−3·0	93
" +diagonally, " "		−3·0	95
" −diagonally, " "		−3·0	95
" high position, " "		−3·0	94
" low position, " "		−3·0	97
" symmetrically, on *lower* wire		−3·0	88
Helix, symmetrically, on upper wire	15, 16	−3·0	+66
	$2\rho=0{\cdot}110^{cm}$	+3·0	−68
	$l=30^{cm}$		

These sudden changes in the values of φ due to magnetization are equivalent to an increase of the rigidity* of steel and I shall therefore describe them as such. If T be the torsional rigidity of a wire, i. e., the reciprocal of the amount of twist per unit length per unit moment of twisting couple; and if G be the absolute rigidity of the material, i. e., the reciprocal of the amount of shear per unit of shearing force, then

$$G=\frac{2T}{\pi\rho^4}.$$

Now if in the present apparatus τ' be the rate of twist in radians and φ the change of τ' due to magnetization; if moreover G_m and G be the rigidities of the magnetized and unmagnetized wires respectively; then since the radii (ρ) are identical

$$G_m\ (\tau'-\varphi)\ =G\ (\tau'+\varphi),$$

which if φ is small in comparison with τ' may be written

$$\frac{G_m}{G}=1+\frac{2\varphi}{\tau'}=1+\mu.$$

* The retrograde motion formerly observed when the upper wire heated to a high temperature (100°−300°), is cooled to the temperature of the lower wire (this Journal, xxxiv, p. 17), might in like manner be used to compute the variations of rigidity due to temperature. In such a case, however, the variations of temperature from the high value to the low value must be as nearly instantaneous as possible, otherwise elastic and viscous detorsions will be erroneously confounded.

A final datum of interest is the *obliquity*, ω, of the external fibre, or the angle in radians between the axis of the wire and any tangent of the helix into which a straight surface fiber, or generatrix has been twisted. This is approximately

$$\omega = \frac{\pi\rho}{180}\tau,$$

τ being the rate of twist in degrees. This variable ω is intended to have no more than geometrical significance. It is known that on twisting and again untwisting an iron wire beyond the elastic limits, the fibers do not return upon themselves to their original forms and positions, but that they become irregularly sinuous lines.

TABLE 5.

Showing the effect of magnetization on the rigidity of soft iron. $l=30^{cm}$.

τ	Nos. 1, 2. $2\rho=0·234$			Nos. 3, 4. $2\rho=0·136$			Nos. 5, 6. $2\rho=0·090$			Nos. 7, 8. $2\rho=0·110$			Nos. 9, 10. $2\rho=0·070$			Nos. 11, 12. $2\rho=0·048$			Nos. 13, 14. $2\rho=0·022$		
°	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$
—0·43	0·8	12	3·2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
—0·75	1·5	18	2·7	0·9	24	3·7	0·6	42	6·4	0·7	34	5·2	0·5	37	5·6	0·3	60	9·2	--	--	--
—1·12	2·3	23	2·3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
—1·50	3·1	30	2·3	1·8	43	3·3	1·2	68	5·2	1·4	54	4·1	0·9	82	6·3	0·6	107	8·2	--	--	--
—2·25				2·7	49	2·5	1·8	75	3·8	2·2	62	3·2	--	--	--	0·9	116	5·9	--	--	--
—3·00				3·6	51	2·0	2·3	78	3·0	2·9	65	2·5	1·8	95	3·6	1·2	131	5·0	0·6	86	3·3
—3·75							--	--	--	3·2	66	2·0	--	--	--	--	--	--	--	--	--
—4·50							3·5	77	2·0				2·7	104	2·7	1·9	148	3·8	--	--	--
—5·25													3·2	103	2·3	--	--	--	--	--	--
—6·00																2·5	156	3·0	1·2	166	3·2
—7·50																3·1	148	2·3	--	--	--
—9·00																			1·7	205	2·6
—12·50																			2·4	220	2·0
—15·00																			2·9	237	1·8

In table 5, I have given values for these variables as obtained with soft iron wires of different thicknesses. The intensity of magnetic field has been stated above (p. 177). Commencing at low values, the rate of twist (τ) is successively increased to the maximum value, which can be imparted, i. e., until, with the occurrence of marked permanent set, the limits of resilience of soft iron are fully reached. After this it was usual to twist the wires further, imparting several thousand degrees of permanent set, whereupon τ was decreased from the maximum to zero. In the table, ω, φ, μ, are means of the values obtained by thus successively increasing and decreasing τ. As before ρ is the radius and l the length of the wires, of which Nos. 1, 2, 3, 4, 5, 6 were drawn down from a single piece of wire, Nos.

7, 8, 9, 10, 11, 12 from a second piece of wire, Nos. 15, 16, 17, 18 from a third piece of wire. Comparison of data is to be made only for wires drawn to different diameters from the same sample of iron.* All wires are annealed at red heat in air.

To this may be added the following data for soft iron filaments drawn from the same wire. ω is the maximum.

No.	2ρ	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$
15, 16	0·032	2·9	212	2·4
17, 18	0·025	2·8	241	2·3

It has been stated that the wires to which table 5 refers were all soft. Their diameters vary over the very large interval $0{\cdot}022^{cm}$ to $0{\cdot}234^{cm}$, and the rates of stored twist from 0·4° to 15°. Nevertheless the maximum obliquity, ω, of the external fiber is nearly the same for all the rods. In other words, the limits of torsional resilience of soft iron are reached when the obliquity of the external fiber exceeds 0·0032 radians.† After this, iron yields to the torsional couple and the result is indefinite permanent set.

Inasmuch therefore as ω is comprehended within about the same interval (0 to 0·003) for all the wires irrespective of thickness, it is expedient to discuss the variation of φ (p. 177) with reference to ω. Indeed the diagram of φ as a function of ω shows the characteristic family of curves with remarkable terseness. φ increases with ω at a rate which is greater in proportion as the thickness of the wires, 2ρ, diminishes, and which decreases and finally approaches zero when ω is a maximum. The detorsion due to magnetization ceases to increase when the sections of the rod slide on each other. Indefinite twisting beyond the elastic limits has no effect so long as the wire is not appreciably hardened. But it is the dependence of φ on ρ to which I desire principally to advert. The following series of values obtain for $\omega=0{\cdot}003$.

* Imperfections in the wire plate prevented me from drawing all the wires from a single sample of iron.

† The literature on torsional strains is so voluminous that I can scarcely suppose similar simplifying observations have not been made. But I have found none. Permanent and temporary torsions have been compared with regard to their relations to stress, to the mechanical condition of the material carrying stress, etc., by Wertheim (Comptes Rend., xl, p. 411, 1855; Ann. de Chim. (3), l, p. 195, 1857); more elaborately even by Wiedemann (Wied. Ann. vi, p. 485, 1879; ibid. vii, p. 496, 1879; Phil. Mag. (5), ix, pp. 1, 97, 1880), and by Perard, (Revue univ. d. Mines, 1879). Reference is also to be made to Tresca (C. R., lxxiii, p. 1104, 1871), to De Saint-Venant, who has investigated the mechanics of ductile substances, and to others. In Wiedemann's last research, correlated values of temporary and permanent torsions are discussed both as they exist immediately after imparting strain and as they exist after an indefinite lapse of time. I have no such comprehensive purpose in view; nevertheless the great convenience of the variable ω is obvious from the way in which I am able to use it.

$2\rho\times10^3=$	234	136	110	90	70	48	22
$\varphi\times10^6=$	30	50	65	80	105	150	240

to which add the values on page 183.

The accelerated rate of increase of φ with ρ as exhibited by these data has suggested the remarks already made, viz: since φ is independent of the sign of the current in the helix it is probable that ρ may be taken sufficiently small to render these phenomena practically available for the measurement of induced or alternating currents. The actual deflection increases with the length of the iron wire. It would be expedient therefore to suspend a light mirror bifilarly from very long filaments of iron and of glass or metal, surrounded by a long cylindrical helix.* The rate of twist temporarily stored in the soft iron filament is the maximum within the elastic limits. I give the following example of deflections produced by the current of an ordinary induction coil, acting on a relatively thick and short iron wire.† The currents are alternately off and on. The two series were made about an hour apart.

Nos. 5, 6; $2\rho=0{\cdot}090^{cm}$; $l=30^{cm}$; deflection=

30	75	40	80	40	83	40	$\varphi=20\times10^{-6}$
52	85	40	75	35	73	35	$\varphi=19\times10^{-6}$

In so thick a wire the heat effect of alternating magnetizations soon becomes apparent. The result is temporary diminution of the rigidity of the wire. Much better results are already apparent when the above thin wires are used. For instance, (same coil),

Nos. 15, 16; $2\rho=0{\cdot}034^{cm}$; $l=30^{cm}$; deflections=

50	180	50	200	70	190	70;	$\varphi=65\times10^{-6}$
70	200	60	200	65	200	60;	$\varphi=69\times10^{-6}$

Further discussion of these results (the errors of which are largely due to the apparatus) is not now expedient.

The values of φ in table 5 are means of five observations with the circuit alternately made and broken. A small amount of permanent detorsion is always imparted to the wire after the magnetism has disappeared, as Wiedemann‡ first pointed

*It is needless to state that I am well aware of the difficulties here in the way, difficulties which Wiedemann has so carefully digested. In my apparatus, however, all pivot and pulley rotations are avoided. I have also repeated the results relating to fine wires at length with very light mirrors, by which no errors due to an asymmetrical mirror adjustments are encountered. The very small couples which come into play in operating with filamentary wires often make damping by submerged vanes objectionable. I have therefore often discarded them.

†The wire plates at my disposal were such that $2\rho=0{\cdot}02$ was the smallest diameter obtainable. But the above series of results are fully sufficient and sufficiently in accordance to justify the inferences drawn.

‡Wiedemann: Galvanismus, p. 689.

out. The following example may be given from very many results of my own. In the case of Nos. 3, 4, the scale readings for currents alternately off and on, were

$\tau=$	0·7°	1·5°	2·3°	2·2°	1·5°	0·7°
(off)	130	110	90	80	50	60
(on)	150	200	185	180	128	100
(off)	80	85	70	70	38	58
(on)	160	188	180	178	130	100
(off)	80	82	70	72	40	60

This is very perceptible in the first part of the measurements where τ or ω increase from zero to the maximum; it generally becomes smaller in amount when ω decreases from the maximum to zero. The method of varying ω from 0 to the high value and then from the high value to zero leads to a cycle of results. In the case of Nos. 7, 8, for instance

$\omega\times10^3=$	0·0	0·7	1·4	2·2	2·9	3·2	ω increasing.
$\varphi\times10^6=$	5	40	57	63	66	65	
$\omega\times10^3$	3·2	2·9	2·2	1·4	0·7	0·0	ω decreasing.
$\varphi\times10^6$	67	64	61	51	28	3	

Observation, which might perhaps be grouped with Mr. Ewing's* phenomena. But in some of the many other like experiments which I made there is an element of vagueness.

Table 5 shows finally that the influence of magnetism on the rigidity of soft iron is greatest when ω is zero. It is obvious since φ increases at a retarded rate while τ or ω increase uniformly, that μ must continually decrease. The large values of μ differ considerably being greater as a rule for smaller diameters. The minimum values of μ obtained are of about the same magnitude, $\mu=0·0021$. If the conditions of indefinite permanent set are such that the obliquity of the external fiber, attain a fixed value, then these conditions imply that the rigidity of steel is changed by magnetization by a fixed minimum amount.

Steel.—In the following table 6, I give the values of φ which hold for steel for the large rate of twist $\tau=6°$. The wires are carefully annealed as described elsewhere. Diameter $2\rho=0·083^{cm}$. A soft iron wire for which maximum ω is only 0·0021 is also tested for comparison.

The curious result of this table is this, that during the first phase† of annealing, the effect of magnetization on the rigidity of steel is almost nil. This effect becomes of marked impor-

* Ewing: Trans. Roy. Soc., ii, 1885, p. 523–4.

† This Journal, xxxi, p. 443, 1886.

TABLE 6.

Rigidity of magnetized Stubs' steel. $\omega = 0{\cdot}0043$.

TEMPER.	$\phi \times 10^6$	$\mu \times 10^3$
Glass-hard	3	0·06
Annealed 100°	4	0·08
" 190°	4	0·08
" 360°	22	0·42
" 450°	25	0·48
Soft steel	41	0·78
Soft iron	95	3·63

tance during the second phase.* In other words, if we suppose the wire to pass continuously from hard to soft, *the increase of the magnetic coefficient of rigidity, μ, is particularly pronounced after the variations of the thermo-electric, the galvanic and the viscous properties of steel have practically subsided.* μ therefore shows close affinities to the induced and to the residual magnetization of an iron-carburet. Agreeing with Wiedemann's results, μ is invariably smaller for steel than for iron. In general if μ be regarded in its dependence both on ω and on hardness, it appears that the increment of rigidity of an iron-carburet produced by magnetization is greater in proportion as the metal shows greater tendency to assume permanent set—a result which applies for iron and for steel.

Lab. U. S. G. S., Washington, May, 1887.

* In a letter to the Journal (xxxiii, p. 308), Prof. W. F. Barrett has taken exception to certain remarks made by Dr. Strouhal and myself (this Journal, xxxiii, p. 35) on phenomena more or less connected with the second phase of annealing. We regret exceedingly to have overlooked Prof. Barrett's papers. Our object, however, was only to give an enumeration of such observations as had occurred to us *incidentally*. Of Gore's discovery we were aware, and the statement is thus made in the text and in U. S. G. S., Bull. 14. Owing to a misconstruction of the foot-note in the Journal (l. c., p. 35, ‡), "ibid." happens to refer to "Wied. Ann." instead of to "Phil. Mag." The reference is otherwise correct.

We avail ourselves of the present opportunity to state that in Prof. J. A. Ewing's paper on the "effects of stress and magnetization on the thermo-electric quality of iron" (Phil. Trans., II, p. 361, 1886) mention is made of our results only in a final note dated Sept. 17, 1886. Our work was accessibly published much earlier (Wied. Ann., xiv, p. 54, 1881; cf. also ibid., vii, p. 408, 1879). We believe we were the first to actually measure Thomson's thermo-electric effect of magnetization as well as to point out its probable relations to the strain of a magnetized rod.

ART. XXII.—*Fauna of the "Upper Taconic" of Emmons, in Washington County, N. Y.* With Plate I. By CHARLES D. WALCOTT.

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IN his second memoir on the "Taconic System,"* Dr. Emmons described two species of trilobites from the black Taconic slate near Bald Mountain, Washington County, N. Y.; *Atops trilineatus* and *Elliptocephala asaphoides.* Subsequently the black slate was referred to the upper division of the Taconic and with it the contained fossils. It is the fauna of which these two species form a part that is embraced within the title of this paper.

From the time of the original discovery and description of the fossils by Dr. Emmons, up to the present, no discovery of Cambrian or First Fauna fossils has been reported from Washington County, except in 1886, when the discovery of Cambrian fossils at Granville was made known.†

At an horizon in Georgia, Vermont, equivalent to that of the "Upper Taconic" series, fossils were found by Noah Parker, Esq., and given to Rev. Z. Thompson, who sent them to Professor Hall who, in 1859, described and referred them to the Hudson River shales (Twelfth Ann. Rep. State Cab. Nat. Hist., 1859). Subsequently, this reference was changed to the Quebec group (Thirteenth Rep., *idem,* 1860), by Professor Hall, and in 1861 (Geol. Surv. Canada; New Species Lower Silurian Fossils, by E. Billings, p. 1, 1861), they were referred to the "Potsdam Group (Primordial Zone)," by Mr. E. Billings. Subsequently Mr. S. W. Ford discovered an equivalent fauna in the vicinity of Troy, N. Y., and concurred with Mr. Billings in referring it to the Lower Potsdam (this Journal III, vol. ii, p. 34, 1871). Afterwards Mr. Ford discovered that the fauna extended farther south and into Columbia County, N. Y.

In the introduction to Bulletin 30, of the U. S. Geological Survey, I have given a summary of our knowledge of this fauna (Taconic or Middle Cambrian) as known to date of publication (1886), and to that I will now add the results of my study of the fauna of the typical "Upper Taconic" area and section in Washington County, N. Y.

* Pamphlet, 1844, reprinted in Agric. N. Y., vol. i, pp. 64, 65, 1876.

† Proc. Amer. Assoc. Adv. Sci., advance sheet, December, 1886; Cambrian Age of the Roofing Slate of Granville, Washington County, N. Y.; Charles D. Walcott.

‡ In a paper read by the writer before the National Academy of Sciences, April 22, 1887, the name Taconic is restricted to the Middle Division of the Cambrian. This paper, with map and sections, will be published within a short time.

Thirty-five species and one variety were found in the even-bedded and conglomerate limestones and the associated slaty argillaceous and siliceous shales. Of these eleven species and one variety were unknown before and are described in this paper. The geographic distribution of the others is given in Bulletin 30, with the exception of their occurrence in Washington County.

The following is a list of the species now in the collections of the U. S. Geological Survey, from Washington County:

Protospongia (loose spiculae).
Ethmophyllum (fragment).
Lingulella cœlata Hall (sp.).
Lingulella Granvillensis, n. sp.
Lingulella, sp. undet.
Linnarssonia Taconica, n. sp.
Kutorgina pannula White (sp.).
Obolella, sp. undet.
Orthis, sp. undet.
Orthis Salemensis, n. sp.
Camarella, sp.?
Fordilla Troyensis Barrande.
Modiolopsis (??) *prisca*, n. sp.
Platyceras primævum Billings.
Hyolithes Americanus Billings.
Hyolithes communis Billings.
Hyolithes impar Ford.
Hyolithellus micans Billings.
Hyolithellus micans var. rugosa, n. var.
Stenotheca elongata Walcott.
Stenotheca rugosa Hall (sp.).
Aristozoe rotundata, n. sp.
Aristozoe Troyensis Ford.
Leperditia (I) *dermatoides*, n. sp.
Microdiscus connexus, n. sp.
Microdiscus lobatus Hall (sp.).
Microdiscus speciosus Ford.
Olenellus asaphoides Emmons.
Olenoides Fordi, n. sp.
Solenopleura (?) *Nana* Ford.
Solenopleura (?) *tumida*, n. sp.
Conocorphye trilineata Emmons.
Ptychoparia, like *P. Adamsi*.
Ptychoparia (?) *Fitchi*, n. sp.
Ptychoparia, sp. undet.
Ptychoparia (?) *clavata*, n. sp.

Of the above, *Lingulella Granvillensis*, *Linnarssonia Taconica*, *Microdiscus connexus* and *Conocoryphe trilineata* are types related more closely to the Lower Cambrian than to the Middle Cambrian fauna. Stratigraphically, they occur low down in the section, and I shall not be surprised if other representative species and some species identical with those from the Lower Cambrian of St. John, N. B., or Newfoundland, are found at about the same horizon.

I have discussed the distribution of the Middle Cambrian or Taconic fauna in Bulletin 30, and the reader is referred to that report for further information.

In a report on the Geology of Washington County, now in the course of preparation, a geologic map will show the distribution of the formations and the localities of the fossils and the vertical range of the latter will be given in the sections.

Lingulella Granvillensis, n. sp.

Plate I, figs. 15–15c.

Shell small, elongate ovate, margins sub-parallel for a short distance at the widest portion about midway of the shell, broadly rounded in front, ventral valve attenuate toward the beak; dorsal valve ovate and rounded at the beak. General

surface depressed convex. Surface marked by fine concentric lines and more rarely, fine radiating lines.

The cast of the interior of the ventral valve shows four narrow elongate scars, radiating from the beak toward the front margin.

A cast of the interior of a dorsal valve shows fine vascular markings and a well-marked median groove, also faint impressions of the anterior adductor muscular scars and, also, what may have been the adjustor muscular scars.

This species is the representative, in the Middle Cambrian of *Lingulella Dawsoni* (Bull. 10, U. S. Geol. Survey, p. 15, 1884), of the St. John formation of the Lower Cambrian. It may also be compared with *Lingulella ferruginea*, which ranges from the Harlech beds through the Menevian and probably into the period of the Lingula flags (Brit. Foss. Brach., vol. iii, p. 337). Dr. G. Linnarsson figures a closely related species from the Paradoxides beds of Sweden (Brach. Par. Beds of Sweden, pl. III, figs. 24–28).

Formation and Localities.—Cambrian. Limestones interbedded in the Taconic shaly slates; two miles south of North Granville; by the roadside a little west of the bridge crossing the Poultney River at Low Hampton; and on the roadside north of school house No. 4, in the northeast part of Whitehall, Washington County, N. Y.

Linnarssonia Taconica, n. sp.

Plate I, figs. 18–18d.

Shell small, rarely exceeding 3^{mm} in length or breadth, usually circular to transversely broad oval. Ventral valve moderately convex; apex excentric; dorsal valve depressed convex; beak obtusely pointed, marginal; surface of the valves marked by fine lines of growth.

In the interior of the ventral valve, near the posterior margin, oblique scars occur, one on each side of the raised rim surrounding the foraminal opening in allied species. From a point of the foraminal rim a narrow depression extends obliquely outward and forward, on each side, so as to enclose a ^ shaped elevation, that is strongly marked in casts of the interior of the valve. The interior of the dorsal valve shows two large oval scars, near the posterior margin, separated by a low ridge that extends over three-fourths of the distance to the front margin.

This species is related to both *L. transversa* and *L. sagittalis*.* It differs chiefly in the characters of the interior of the dorsal valves. As yet none of the specimens have shown the ventral

* This Journal, III, vol. ix, pp. 114–117.

valve to be perforate, this is owing probably to the minute size of the opening and the imperfection of the specimens which have been examined.

This is the first instance known to me of the occurrence of this genus in association with the Taconic or Middle Cambrian faunas, as it is essentially a Lower Cambrian type both in New Brunswick, Newfoundland, and Sweden and Wales.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates, at Rock Hill school house (No. 8), near North Greenwich; 1½ miles east of North Greenwich; lowest fossiliferous horizon on D. W. Reid's farm, 1½ miles west of North Greenwich; west summit of Bald Mountain, in the town of Greenwich; two miles south of North Granville; on the roadside just west of Low Hampton crossing of the Poultney River; and one mile south of Shushan, all in Washington County, N. Y.

Kutorgina pannula White, (sp.).

Plate I, figs. 14–14b.

Kutorgina pannula.—See Bull. 30, U. S. Geol. Survey, p. 105, 1886.

The specimens of this species, from Washington County, are hardly distinguishable from those obtained on the slopes of the Highland range in southern-central Nevada. In Nevada, the species occurs at the lowest known fossiliferous horizon and ranges up through 1400 feet of strata, but not into the Upper Cambrian or Potsdam horizon.

The edges of the reticulations on the surface of the New York specimens are usually sharper than those of the Nevada form, but I do not think that the difference is of specific importance.

Its occurrence, in Washington County, in the lower beds of the Taconic formation, is of great interest, as it adds another connecting link between the widely separated localities of this fauna in Nevada and New York.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates, on the roadside, just west of Low Hampton crossing of the Poultney river and two miles south of North Granville, Washington County, N. Y.

Orthis Salemensis, n. sp.

Plate I, figs. 17–17*a*.

Shell about the average size of the Cambrian species of the genus. Transversely subquadrilateral; front broadly rounded and slightly sinuate midway: hinge line as long as the greatest width of the shell.

Ventral valve convex, most elevated about one-fourth the distance from the beak to the anterior margin; beak small and incurved to the margin of the medium sized area; the surface of the area and the foramen have not been observed; mesial sinus broad and shallow, it is marked by a low median rib and, laterally, by two costæ on each side, a third appearing just outside the sinus.

The dorsal valve, associated in the same hand specimen of limestone, is slightly more convex; frontal margin with a rather deep sinuosity to receive the projection of the ventral valve; median fold broad and but slightly elevated, marked by two or three low costæ; the beak appears in the broken specimen in the collection to be scarcely elevated above the surface of the shell, and to terminate at the cardinal margin; area unknown.

The surface of both valves is marked by fine concentric lines of growth, and low, rounded costæ, varying in number from six to seven, as in the specimens figured, to twelve or fourteen in other specimens.

In the broad costæ and the general aspect of the shell this species is unlike any known to me from the Cambrian.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates, one and one-half miles south of Salem; one mile south of Shushan, and near Rock Hill schoolhouse (No. 8), Greenwich, Washington County, N. Y.

Hyolithellus micans var. rugosa, n. var.

Plate I, fig. 10.

This name is proposed for a variety of *Hyolithellus micans* that has well-marked concentric ridges with longitudinal striæ between them. The substance of the shell appears to be similar to that of *H. micans*. (See Bull. 30, U. S. Geol. Survey, p. 142.)

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates on the roadside just west of Low Hampton crossing of the Poultney river; lowest fossiliferous horizon on D. W. Reid's farm, and on hill back of Reid's farmhouse, one and one-half miles west of North Greenwich; two miles south of North Granville; and in the north part of Easton, about one mile south of the village of Greenwich, Washington County, N. Y.

Modiolopsis ?? prisca, n. sp.

Plate I, fig. 19.

The only specimen of the species known to me is the cast of a right (?) valve, 2^{mm} in length. It is transversely oval in out-

line and rather strongly convex; the beak is subcentral and curves toward the hinge line, but does not reach it; an oval muscular scar is situated just within the pallial line, at the supposed anterior end; pallial line simple, continuous as far as observed.

The minute size and the fact that we have only the cast of the interior of the valve, render it very difficult to determine the correct generic relations of this shell. The nearly central position of the beak distinguishes it from all known species of Modiolopsis; while the muscular scar and pallial line, with the oval form, relates it to *Modiolopsis curta* of the Hudson River formation. The discovery of the character of the hinge line may place it in a genus of the Arcadæ; but, at present, I do not wish to state more than that I think it is undoubtedly a lamellibranchiate shell. With the possible exception of *Fordilla Troyensis*, which, possibly, may be the shell of some Estheria-like crustacean, I know of no true lamellibranchiate shell in the Cambrian system of America, as defined in 1886. (This Journal, vol. xxxiii, p. 147, 1886.)

Formation and locality.—Cambrian. Limestone, interbedded in shaly Taconic slate, on the roadside north of School-house No. 4, in the northeast part of Whitehall, Washington County, N. Y.

Leperditia (I) dermatoides, n. sp.

Plate I, figs. 13, 13*a*.

Outline of the valves, elongate, suboval, with the extremities of the hinge line rounded, subangular; moderately convex, sloping more rapidly to the ventral than the dorsal margin; in many specimens, however, it is difficult to determine the ventral from the dorsal margin, owing to their almost equal curvature and similar rounding of the ends; the hinge line is arched and but slightly marked. It is difficult to determine the anterior and posterior ends of the valves in many of the specimens, but in others the narrower end is considered as the anterior, and a small, round depression on the inner side of the valve places the muscular scar well toward the posterior end. The scar is barely visible on the outer surface.

The test is finely punctate, and so thin that it wrinkled in some instances like a membrane or skin.

Length of undistorted specimen, 6^{mm}; greatest height, $3{\cdot}5^{mm}$.

The strongly punctate surface is so unlike that of all the species referred to Leperditia that it may be that this species should be referred to a distinct genus.

In its punctate surface and general form it is unlike any other species known to me.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slate; north part of Easton, about one mile south of the village of Greenwich; on the west side of D.W. Reid's farm and on the summit of the hill, northwest of his farmhouse, about one and one-half miles west of North Greenwich; about three miles northeast and one and one-half miles east of North Greenwich; near Rock Hill school-house (No. 8), east of North Greenwich; and one mile S.S.E. of Battenville, in the town of Jackson, Washington County, N. Y.

ARISTOZOE TROYENSIS Ford.

Plate I, fig. 8.

Leperditia Troyensis Ford, 1873. This Journal, III, vol. vi, p. 138; Walcott, 1886, Bull. 30, U. S. Geol. Survey, p. 146.

The discovery of another specimen of this species enables me to refer it to the genus Aristozoe of Barrande. The thin test, grooved and reflected ventral margin, anterior tubercle and general form, all serve to connect it with that genus. In Bull. 30, U. S. Geol. Survey, a figure is given of the right valve, and I am now able to figure the left valve. The tubercle on the anterior end is elevated and directed forward.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates, on the ridge east of the city of Troy, N. Y.; also at the lowest fossiliferous horizon, on the west side of D. W. Reid's farm, about one and one-half miles west of North Greenwich, Washington County, N. Y.

ARISTOZOE ROTUNDATA, n. sp.

Plate I, fig. 9.

General outline of the valves subrotund, with the exception of the nearly straight hinge line; anterior end slightly narrower than the posterior; general surface rather strongly convex, marked all around, except along the hinge line, by a strong marginal groove within a rounded marginal rim; a single elongate protuberance extends from the main body of the shell upward, just within the anterior marginal groove and the hinge line, where it is most prominent, and separated from the main body of the valve by a broad sulcus extending from the hinge line down on the valve over two-fifths the distance to the ventral margin.

The shell is thin and apparently very finely granulose.

A comparison with the types of the genus Aristozoe shows this species to be congeneric with them and specificially distinct from any described species of the genus. *Aristozoe*

*bisulcata** has a similar outline, but the tubercle is unlike that of *A. rotundata* and it is differently situated on the valves.

It is distinguished from *A. Troyensis* by its form and also the elongate tubercle or ridge.

The discovery of this species and the generic identification of *A. Troyensis* adds another Silurian genus to the Cambrian fauna and extends its range from the true Silurian down to the middle Cambrian. As yet I do not know of the presence of the genus in the Lower Silurian (Ordovician) rocks.

Formation and locality.—Cambrian. Limestones, interbedded in the shaly Taconic slates on M. C. Tefft's farm, about two miles southeast of North Granville, Washington County, N. Y.

MICRODISCUS CONNEXUS, n. sp.

Plate I, figs. 4, 4*b*.

Head semicircular, convex; bordered by a well-defined rim that is crenulated across the front and narrowed posteriorly toward the glabella where it terminates; cheeks most prominent at the postero-lateral portion, from whence they slope to the deep dorsal furrow about the glabella; the glabella and its backward spinose extension form, together, a fusiform median lobe, as there is no occipital furrow or ring, and the glabella and the spine are continuous. The glabella approaches the frontal margin more closely in some specimens than in others. The surface of both the head and pygidium appears smooth under a strong magnifying glass.

A glance at the head of this species recalls *Microdiscus punctatus*, *M. punctatus* var. *Pulchellus* and *M. Dawsoni* of the Lower Cambrian. It has the frontal rim and form of *M. Dawsoni*, but it is a smooth, not granulose species; and the associated pygidium is unlike that of *M. Dawsoni*. To *M. punctatus* it is related by its general form, but differs in the more coarsely crenulated margin, the form of the cheeks and its smooth surface, also in the characters of the associated pygidium. The presence of this type of the genus Microdiscus in association with well-known Middle Cambrian or Taconic fossils is another link between the Lower Cambrian fauna of New Brunswick and the Middle Cambrian fauna. It is the first instance known to me of the occurrence of a species with the long nuchal spine above the Paradoxides horizon in America.

Formation and localities.—Cambrian. Limestones, interbedded in the shaly Taconic slates, on the roadside just west of Low Hampton crossing of the Poultney river, one mile west of North Hebron, and two miles south of North Granville, Washington County, N. Y.

* Barrande; Syst. Sil. Boh., vol. i, Supplement, p. 477, 1872.

Olenoides Fordi, n. sp.

Plate I, figs. 5–5*b*.

Head rather strongly convex, frontal margin rounded, moderately elevated and separated from the glabella by a groove of medium width and depth. Glabella prominent, subquadrilateral, narrowing very slightly towards the broadly rounded front; three pairs of short, obscure furrows occur well down toward the dorsal furrow surrounding the glabella; occipital ring well defined and bearing a spine that projects upward and backward. Fixed cheeks about one-half the width of the glabella and curving slightly downward from the glabella to the palpebral lobe; ocular ridge strong and extending to and connecting with the rim of the palpebral lobe; eye situated midway of the facial suture and rather prominent in size and position; postero-lateral limbs short, broad and deeply grooved by the furrow within the posterior margin; at a point midway of the latter, a broad angle is formed and a rudimentary spine indicated.

The direction of the facial suture is well shown in the figure of the head on the plate. A free cheek, associated in the same hand specimen of rock, shows a low visual surface for the eye, a marginal rim similar to that between the facial sutures, and a short spine at the postero-lateral angle.

The associated pygidium is moderately convex, and bears a narrow, convex, median lobe, divided into five transverse segments and a short terminal segment; the lateral lobes are marked by four coalesced segments, indicating the continuation of the anterior segments of the median lobe; although broken by the smooth border, the segments may be traced into the four anterior of the six spines of the outer margin. Surface granulose under a strong magnifier.

A comparison with *Olenoides quadriceps* and *O. Wasatchensis* (Bull. 30, U. S. Geol. Survey) shows a marked resemblance in the pygidiæ, but, in the head certain differences occur, such as the narrower glabella and the wider furrow between the glabella and frontal rim of *O. Fordi.*

The species referred to this genus from the American Cambrian strata are: *O. Nevadensis* (the type), *O. Marcoui*, *O. quadriceps*, *O. Wasatchensis* and *O. Fordi.* In Bulletin 30, U. S. Geol. Survey, I referred *O. typicalis*, *O.? flagricaudus*, *O. levis* and *O. spinosus* to Olenoides, but since obtaining a nearly perfect specimen of Olenoides, closely related to the type species, I am convinced that the last mentioned four species belong to an as yet undescribed genus. This genus will be characterized in a future paper.

O. Fordi occurs in the lowest horizon of the Taconic slaty series now known to me, and is associated with *Olenellus asaphoides*, *Microdiscus connexus*, *Linnarssonia Granvillensis*, etc.

The specific name is given in honor of Mr. S. W. Ford, who has done such excellent work at this horizon about Troy, and Schodack Landing, N. Y.

Formation and localities—Cambrian. Limestones interbedded in shaly Taconic slates, on the roadside just west of the Low Hampton crossing of the Poultney River, two miles south of North Granville, and one mile north of Middle Granville, Washington County, N. Y.

SOLENOPLEURA ? ? TUMIDA, n. sp.

Plate I, figs. 2–2*a*.

This species differs from *Solenopleura ? Nana*, with which it is associated at several localities in having a more tumid glabella, narrower frontal lobe and in the absence of an ocular spine. Some specimens of *S.? Nana* have almost as tumid a glabella, but, usually, it is less elevated.

The generic reference is provisional, as both *S. ? tumida* and *S.? Nana* appear to belong to a genus distinct from the typical species of Solenopleura.

Formation and localities.—Cambrian. Limestones interbedded in the shaly Taconic slates near Rock Hill school house, (No. 8) east of North Greenwich; $1\frac{1}{2}$ miles east and 3 miles northeast of North Greenwich; on the west side of D. W. Reid's farm about $1\frac{1}{2}$ miles west of North Greenwich; $\frac{1}{2}$ mile east of South Hartford post office; in the village of East Hebron; on the roadside just west of Low Hampton crossing of the Poultney River and one mile south of Shushan, Washington County, N. Y.

SOLENOPLEURA ? NANA Ford.

Plate I, figs. 1–1*d*.

Solenopleura Nana Ford, 1878. Amer. Jour. Sci., III, vol. xv, p. 126; Walcott, 1886. Bull. 30, U. S. Geol. Survey, p. 214.

This species was not illustrated by Mr. Ford, and the specimens I had, when preparing Bulletin 30, U. S. Geol. Survey, were so poor that the illustrations then given were not satisfactory. Among the specimens in the collections from Washington County I find considerable variation in the convexity of the glabella and also in the granulose surface; and I suspect that with a large series of more perfect specimens there could be separated a variety if not a distinct species. The pygidium associated with *S. ? Nana* at Troy and also in Washington County, two miles south of North Hebron and one mile north of Middle Granville, has a spinose margin that recalls the pygidiæ of certain species of Peltura from the Swedish Cambrian.

Conocoryphe trilineata Emmons (sp.)

Plate I, figs. 7–7*b*.

For synonymy see Bull. 30, U. S. Geol. Survey, p. 203.

When examining the collections at Williams College, in 1886, I found the specimen from which the figure of *Atops trilineatus*, in Emmons's American Geology, pl. i, fig. 16, was drawn, and, through the courtesy of Professor S. W. Clarke, I have had a more accurate drawing made of it than the published figure. A study of the specimen, in connection with heads and pygidiæ collected from the original locality, shows that the species should be referred to the genus Conocoryphe,* as restricted by Corda, although *C. trilineatus* differs from the type of the genus *C. Sulzeri* in having a smaller pygidium and seventeen instead of fourteen thoracic segments; differences, however, of a specific rather than generic importance. The slender free cheeks have not yet been identified.

On plate xxvii, Bull. 30, U. S. Geol. Survey. figs. 1*a*, 1*b*, there are figures drawn by Mr. Ford of the species as identified by him at Troy, N. Y. The pygidium is similar to that associated with *Solenopleura? Nana* at other localities, and the head may be that of this species, but it is uncertain, owing to the imperfection of the specimens.

Formation and localities.—Cambrian. In black, argillaceous, shaly Taconic slate on the roadside near the old Reynolds Inn, now D. W. Reid's farm buildings about one mile west of North Greenwich; also in the northern part of Easton, about one mile S.S.W. of the village of Greenwich, Washington County, N. Y.

Ptychoparia Fitchi, n. sp.

Plate I, fig. 6.

This species is founded on a minute head that occurs in association with *Microdiscus connexus* and several other species of the lower horizon of the Taconic slate series. The elongate unfurrowed glabella, wide fixed cheeks and strongly granulose surface, all unite to give it a facies unknown in any other species with which I am acquainted.

Formation and locality.—Cambrian. In limestone, interbedded in the shaly Taconic slates, two miles south of North Granville, Washington County, N. Y.

* Mr. S. W. Ford states that this species has been shown to belong to the genus Conocoryphe (Amer. Jour. Sci., III. vol. xix, p. 152), but, up to the present time, I have not seen any proof of its true generic relations nor could it well be shown before more perfect specimens of the head were obtained than those illustrated by Emmons.

PTYCHOPARIA ? (*Subgenus?*) CLAVATA, n. sp.

Plate 1, fig. 3.

This is a minute trilobite, whose true relations are unknown. With the exception of its clavate glabella, it is related to *Solenopleura? Nana* and *S.? tumida* by the course of the facial sutures, wide fixed cheeks and small eye lobes.

Formation and localities.—Cambrian. Limestones interbedded in the shaly Taconic slates, 1¼ miles south of North Granville; on the roadside a little north of school house No. 4, in the north-east part of Whitehall; on the roadside just west of the Low Hampton crossing of the Poultney River; and near Rock Hill school house (No. 8), about a mile east of North Greenwich, Washington County, N. Y.

DESCRIPTION OF PLATE I.

[The natural size of the specimens is indicated by the lines beside the figures.]

Page.

FIGURE 1.—*Solenopleura? Nana* Ford 196
1, smooth variety of head; 1*a*, side outline of 1; 1*b*, side view of a granulose head that has faint glabella furrows; 1*c*, 1*d*, pygidium associated with the heads of this species.

FIGURE 2.—*Solenopleura? tumida*, n. sp. 196
2 and 2*a*, top and side views of head, except free cheeks.

FIGURE 3.—*Ptychoparia* (?) *clavata*, n. sp. 198

FIGURE 4.—*Microdiscus connexus*, n. sp. 194
4, 4*a*, summit and side views of head; 4*b*, associated pygidium.

FIGURE 5.—*Olenoides Fordi*, n. sp. 195
5, head, except free cheeks; 5*a*, associated pygidium; 5*b*, associated free cheek.

FIGURE 6.—*Ptychoparia* (?) *Fitchi*, n. sp. 197
6, head, except free cheeks.

FIGURE 7.—*Conocoryphe trilineata* Emmons (sp.) 197
7, finely preserved head with the exception of the narrow free cheeks; 7*a*, figure of specimen described by Dr. Emmons in his American Geology, pl. i, fig. 16; 7*b*, pygidium associated with heads and fragments of the thorax.

FIGURE 8.—*Aristozoe Troyensis* Ford 193
8, cast of left valve.

FIGURE 9.—*Aristozoe rotundata*, n. sp. 193
9, cast of the right valve. A row of vascular markings are quite distinctly shown on the lower portion of the valve.

FIGURE 10.—*Hyolithellus micans* var. *rugosa*, n. var. 191
10, enlargement of a fragment to show the rugose surface.

FIGURE 11.—*Stenotheca rugosa* Hall (sp.) ....
11, 11*a*, side views of two specimens to show the variation in the concentric undulations of growth; 11*b*, enlargement of the surface of 11. (For description of this species see Bull. 30, U. S. Geol. Survey, p. 128.)

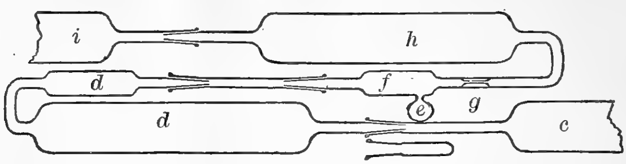
ART. XXIII.—*On the amount of Moisture remaining in a Gas after drying by Phosphorus Pentoxide*; by EDWARD W. MORLEY.

I HAVE now determined the amount of aqueous vapor left in a gas after drying it with phosphorus pentoxide, by the method applied in the case of sulphuric acid.* The process consists in drying the gas with phosphorus pentoxide, and then passing it through a weighed apparatus in which the gas is first slightly moistened, then much expanded, and lastly again dried by phosphorus pentoxide. If the weight of the apparatus decreases, the loss is due to the moisture left by phosphorus pentoxide in that volume by which the gas passing out of the apparatus exceeds the gas entering it.

If it were required in this matter to determine with some precision a physical constant, numerous experiments would be needed, and the results of the experiments now completed, show that each experiment would have to be continued for some years. But for settling a practical question concerning chemical manipulation, the two experiments now completed

* This Journal, vol. xxx, p. 141.

within three or four months may perhaps be thought sufficient. I therefore give some account of them, referring to the previous paper for further explanation of the principle of the method.



Part of the apparatus used is shown in the figure. *c* consists of three parts fused together: a Liebig's bulb tube filled with strong pure sulphuric acid, to effect the preliminary drying of the gas; a tube filled with powdered potassium hydroxide, to remove vapors of sulphuric acid; and a tube filled with phosphorus pentoxide mixed with glass wool, and having a plug of cotton wool at the exit of the gas. *dd* is a tube used as a counterpoise for the tube *efgh*, and having very nearly the same volume and the same surface as the latter. *efgh* consists of four parts. In *f*, air dried in *c* is made to take up a small quantity of moisture: it contains moistened calcium chloride. In *e*, at the beginning of an experiment, is contained about a gram of water: the size and length of the tube connecting *e* with *f* are used to adjust the absorption of water by the calcium chloride to the other circumstances of the experiment. At *g*, the tube connecting *f* and *h* consists in part of a very fine capillary tube. The diameter of this tube is reduced by fusion till the pressure of the atmosphere will force two or three cubic centimeters of air through it in a minute, provided that a vacuum be maintained at one end. In *h* is contained phosphorus pentoxide mixed with glass wool, and having a plug of cotton wool at the exit of the gas. *i* also contains phosphorus pentoxide: it is fused to a tube leading to a large reservoir connected with an air pump.

During the passage of a current of gas through the apparatus, *dd* and *efgh* have to be connected to each other and to the drying tubes *c* and *i*. Caoutchouc connectors would be a fruitful source of error in an experiment of such delicacy as the present. Whether the fact be that it is impossible to make caoutchouc tubes absolutely dry, that moist air diffuses through them, even against a greater internal pressure, or that gradual oxidation produces water as well as carbon dioxide, I have found it impossible to use such connectors when it was necessary to avoid introducing water into the apparatus at a rate of even a decimilligram in a day. All connections required

were therefore made by joints ground in a special way. Take for example the connection between *c* and *d*. *d* is to be weighed. The end of *d* is ground to a cone about fifteen millimeters long. The end of *c* is ground to a hollow cone about ten millimeters long, so as to leave about five millimeters of the end of *d* free from contact with *c* when thrust into it. If now a little fat of suitable consistency is put on the end of *c*, *d* thrust into it, and both gently warmed, a joint is made which is absolutely air-tight for small differences of pressure, provided that the layer of fat is not disturbed after solidification. It will be observed that at the joint between *h* and *i*, the difference of pressure is about an atmosphere; but any slight leakage here would only affect the measurement of the volume of air used in the experiment, and would not affect the weight of the weighed apparatus, because a slow current of moist air entering here would be swept along into *i* by the current of three liters an hour passing out of *h* during the experiment. Further, direct experiment with such a joint showed a leakage of much less than a cubic millimeter of air in three months. It may be fairly assumed that the *diffusion* of moisture through the layer of fat in each joint is negligible for the present purpose. In any experiments where this assumption ought not to be made, the joint would be surrounded by air kept dry with phosphorus pentoxide, or by a vacuum. It may be added that if such a layer of fat has to be disturbed after solidification, as by turning a plug or stopper, the problem of making an absolutely air-tight joint is very different from that in the present case.

The weighing of drying tubes with an error of less than a decimilligram is difficult. Two hollow cones were ground to fit each end of the tubes to be weighed; one was used to connect this tube with other parts of the apparatus, and the second was fused together, making a cap, as shown between *c* and *d*. Caps 1 and 2 fitted *dd*, caps 3 and 4 fitted *efgh*. All these caps having a suitable quantity of fat applied, 1 and 2 were counterpoised against 3 and 4, and the difference of weight determined by careful weighings for a few days. The end of *h* was withdrawn from *i*, carefully wiped free from the fat which had made this joint tight, and 1 was put in place; 2, 3 and 4, were successively put in place, and the barometer and thermometer were noted. Each tube was carefully washed, and then polished with a dry cloth, but nothing was brought near the fat on the caps. The difference in weight between *efgh*, caps and fat, and *dd*, caps and fat, was determined by weighings for several days. The hygroscopic surface of the tube *efgh* was so nearly equal to that of *dd*, and the volumes of air displaced by *efgh*, on the one side, and by *dd* and the

required brass weights on the other side were also so nearly equal, that no variations of a decimilligram were noted in the eight, ten or fifteen days used in the weighings. Subtracting the difference of weight of caps and fat from the difference of total weight, we have the difference of weight of tubes *efgh*, and *dd* with their contents, solid or gaseous. Now, since care was taken to close the tubes at the end of the experiments at an hour when the barometer and thermometer showed the weight of a given volume of air to be the same as when the tubes were closed at the beginning of the experiment, a comparison of the two differences thus determined at the beginning and end of an experiment would show the loss of weight of the contents of *efgh*. It was assumed that the difference of volume between $H_2O+P_2O_5$ before; and $2HPO_3$ after, an experiment was negligible for the quantity of water used.

Using many precautions too minute to be detailed, there was no difficulty in determining the difference of weight of the two apparatus as accurately as the difference of two brass weights. The whole weight on each pan was 35 grams; a Becker balance intended to carry 100 grams in each pan was used. Weighings could therefore be made to the fortieth of a milligram. The tubes were left untouched for many days, in a room without artificial heat, surrounded by rooms kept at a pretty constant temperature, and their weights compared from twenty to fifty times. The results obtained were as constant as were obtained on the same balance in ascertaining the relations of the set of weights used with it.

The details just stated show that it is not impossible to secure equality of hygroscopic state in two equal surfaces freshly made of the same glass. The outer surfaces of *dd* and of *efgh* therefore do not interpose any serious difficulty in the way of accurate weighing. But the inside of *dd* has to be in the same hygroscopic state at the beginning and the end of an experiment lasting many weeks.

To secure this, dry air from *c* was passed through *d* for a long time while it was heated to 200° or 250° C. When *d* had thus been made as dry as possible at this temperature, the end of *d* remote from *c* was closed with its weighed cap and charge of fat. *efgh* was connected with *i* at one end, and closed by its cap at the other. *dd* and *efgh* were left side by side for a day to attain equality of temperature and pressure, disconnected from *c* and *i*, and closed with their second caps at the same time. After weighing, *dd* and *efgh* were connected as shown in the figure. Now, since during the experiment, only air dried in *c* passes through *d*, and since the experiment proves that this air contains no appreciable amount of moisture, the interior of *d* absorbed no moisture; and it lost none, for its

temperature was far below that at which it had been dried. Therefore the hygroscopic state of the interior was constant.

When *dd* and *efgh* had been prepared and weighed, they were connected, as described to the tube *i*. This tube, intended to prevent the passage of moisture from the air pump to the tube *efgh*, was fused to a tube carrying a syphon barometer gauge, and a mercurial stop-cock leading to the air-pump, and connected to a copper vessel holding 54·1 liters. The connection of the glass tube to the copper reservoir was immersed in water: this water jacket and the mercurial stop-cock secured the certainty that all air entering the receiver must come through the tubes *c* to *i*. The pressure in the receiver was reduced till the flow through *h* was about three liters an hour, and was measured on the gauge. When the pressure had risen by a suitable amount, it was again measured, and again reduced. When the water in *e* and *f* was exhausted, air was slowly admitted to the receiver by breaking off a sealed capillary tube; when the pressure in the receiver was equal to that of the atmosphere, a free communication was made between the air and the tubes *i* and *c*, and when the air had a suitable density, the caps were applied and weighings made as already described.

In an experiment lasting through December, 1886 and January, 1887, 726 liters of air passed through *c* and *d*. They were expanded to 2428 liters in *g*, and passed through *h* at the rate of 70 liters in a day. The excess of the volume passing out was 1702 liters, and the loss of weight in the tube *efgh* was rather less than the twentieth of a milligram. In an experiment lasting from February to April, 1887, the volume of air entering was 211 liters, the expanded volume, which passed at the rate of 75 liters in a day, was 2841 liters, and the excess was 2630 liters. The loss of weight of the apparatus was rather more than one twentieth of a milligram. The measured volumes may well be in error by one or two per cent.

The weight of aqueous vapor left in a gas passing at a rate of three liters in an hour through a tube two centimeters in diameter and eight centimeters long compactly filled with phosphorus pentoxide and glass wool, is therefore so little, that in 4300 liters it cannot be detected with much probability by even the most delicate weighing.

It is obvious that if at some future time physicists should need to know the tension of the vapor of water in presence of phosphorus pentoxide, an experiment by this method must be greatly prolonged. With a current of three liters an hour, the effect measured was not over a decimilligram in two months. To obtain some such quantity as ten milligrams might therefore require ten years. But for the purposes of the chemist the present two concordant results may for a time be sufficient.

Van der Plaats, giving more than sufficient credit to the previous experiments on sulphuric acid, has suggested in a note that the experiments were but few in number, were in fact, but preliminary (provisoire) and that it would have been better to produce the current of air by pressure. With the connections used, whether a current be produced by excess or defect of pressure is perfectly indifferent. The leakage at any joint was proved to be less than a tenth of a cubic millimeter in the time of an experiment. The experiments were also of such number and character as to be final (at least for the present), as to the question whether the use of sulphuric acid for drying gases in the ordinary course of analysis or research introduces any measurable error.

Our knowledge of the behavior of the three principal drying agents is now as complete as is needed at present. Dibbits showed how much moisture is left unabsorbed by calcium chloride at different temperatures. He also established the difference between the amounts left unabsorbed by sulphuric acid and by phosphorus pentoxide. I have shown previously that sulphuric acid leaves unabsorbed not far from a fourth of a milligram of moisture in 100 liters of a gas. Now it appears that the moisture left unabsorbed by phosphorus pentoxide, if capable of determination, may be very roughly stated as possibly a fourth of a milligram in 10,000 liters.

749 Republic St., Cleveland, Ohio, May, 1887.

Art. XXIV.—*Is there a Huronian Group?** by R. D. Irving.

Synopsis of Contents.

I. Starting with a statement of the values of the terms *System*, *Group* and *Formation*, as used in the nomenclature recently proposed by the Director of the United States Geological Survey, this paper enquires whether there can be carved off from the upper part of the great complex of rocks ordinarily known as Archæan, a *Huronian* series, entitled to rank with such groups as the Cambrian, Silurian, etc.

II. The rock series of the north shore of Lake Huron, between the Mississagui and St. Mary's rivers, mapped by Logan on Plate III of the atlas to the Geology of Canada, 1863, is the original or typical Huronian, and no other. The enquiry must then begin with this region.

III. This typical series of rocks is next shown to be entitled to the group rank by (1) its intrinsic characters, and (2) its structural, and consequently its chronological separateness from the older Archæan, and younger Cambrian and pre-Cambrian rocks of the region.

IV. The so-called Archæan rocks of the Marquette, Menominee, and Penokee districts of the south shore of Lake Superior are next considered, in the order of the districts named, and are shown to present the same divisibility into an upper detrital, and a lower crystalline schist member, which members are to be correlated respectively with the type Huronian, and with the crystalline rocks beneath

* Read by invitation before the National Academy of Sciences, at Washington, D. C., April 22, 1887.

t. This correlation is supported by: (1) a similarity of structural relations between the series correlated, in the different districts; (2) a similarity of lithological characters, group for group, and (3) a similarity in general stratigraphical position.

V. Attention is next invited to the region north of the western half of Lake Superior, the so-called Animiké series of which is the equivalent of the Penokee iron-bearing series, and hence of the original or type Huronian.

VI. The iron-bearing belt of the Vermilion Lake region of northern Minnesota is next considered, and found to furnish a case where newer detrital rocks have been folded in with the basement rocks, so as largely to obliterate the appearance of unconformity, a true schistose structure having at the same time been developed in the detrital series.

VII. The several discordances thus passed over in review—i. e., those respectively beneath the Animiké series, the Penokee iron-bearing series, the type Huronian of Lake Huron, the Marquette iron-bearing series, the Menominee iron-bearing series, and the Vermilion Lake iron-bearing rocks—form, in the order named, a graded series as to the degree of modification of the original discordances. When the subsequent disturbance has been great, cases must arise where the distinction between the two sets of rocks becomes very difficult, or even impossible.

But in all the several districts named there is plainly recognizable the same discordance, due to the same orographic disturbance, between the same sets of rocks.

Throughout the region stretching from the north shore of Lake Huron westward to the Mississippi River, in central Minnesota, there is recognizable the following order of succession, beginning below:

(1) The great basement or *Laurentian* complex of gneiss, granite and crystalline schists; as to whose further divisibility no opinion is now offered. This is separated by a great discordance from

(2) The *Huronian*, a detrital iron-bearing series. A further discordance severs this from

(3) The *Keweenawan* series of interleaved detrital and eruptive beds. This series again is entitled to the group rank. Above the Keweenaw series and separated from it by yet a third great discordance, follows:

(4) The *Potsdam* or Upper Cambrian sandstone.

VIII. Correlations of rocks of regions other than that now especially referred to, with the type Huronian, have generally been made without much foundation, having been based only on similarities to a fictitious lithological standard. Cautiously made correlations, however, for regions not too distant from each other, may have some value when based on a comparison of great discordances; since these discordances indicate the intervention of mountain-making movements of a necessarily wide-spread influence; but the more general correlation—collectively—of all the clastic groups, which in any one region intervene between the Cambrian and the basement crystallines, with any group or groups falling within the same interval in other regions, is the only one which is at present of any general application.

IX. The Huronian and the Keweenawan—and also such other groups of rocks as are found in other portions of the world beneath the Cambrian base, and above the Archæan schists—should be admitted to the geological column with the group rank. This admission, however, renders desirable a modification of the lower part of the column. It is suggested therefore that the term Archæan be used to cover only the pre-Huronian basement crystallines; that the Cambrian group remain as the basal member of the Palæozoic System, and that the new system name *Agnotozoic*, first proposed by Professor T. C. Chamberlin, be used to cover, at least provisionally, such clastic groups as intervene between the Cambrian base and the Archæan schists.

I. According to the system of nomenclature recently proposed by the Director of the United States Geological Survey,*

* As set forth in a paper presented at the International Geological Congress, (held in Berlin in 1885), and published in French at Paris in 1886, under the title of "Methodes de Cartographie Geologique Employés par L' United States Geological Survey."

the great fossiliferous rock complexes are classed in three orders of magnitude, namely: the *System*, the *Group*, and the *Formation*. Of these classes the most comprehensive is the *System*, which term is applied to those great divisions of the geological column which are defined by palæontology, and are recognizable the world over. Such are the Cenozoic and the Mesozoic Systems. Next in order comes the *Group*, which term is designed to cover those great sub-divisions of the Systems which are "defined above all by palæontology, and subordinately by petrography, or are admitted by all geologists, for motives in part arbitrary. These are the groups. Those admitted by the Survey have been discovered in various countries; they have probably a universal distribution,* comprising all the formations of known clastic origin, and appear to be approximately comparable among themselves as to volume. It is not maintained that their limits are clearly marked, nor that they can be strictly traced along equivalent stratigraphical levels. Nor yet is it held that the testimonies of the different classes of fossils—vertebrates, invertebrates and plants—are always consistent with each other, or with that of petrography, as to their limits. These divisions are, then, to a certain extent arbitrary. We may increase or diminish their extent from time to time by adding or withdrawing formations in the neighborhood of their respective boundaries, just as the orders of biology are perpetually modified. . . . "† Such are the Cambrian, Silurian, Devonian and Carboniferous Groups. These generally recognized subdivisions of the geological column are *groups*, especially in the sense that they include each a number of subordinate divisions distinguishable from one another petrographically, genetically, and often even palæontologically. These subordinate members finally are the *Formations* of this system of nomenclature, though the use of the term formation is allowed also in a vaguer sense to cover any rock mass whose distinction from the surrounding masses is desirable on one ground or another.

In the paper referred to, this classification is proposed only for what are in it termed the clastic groups—*clastic*, in the sense that they are formed mainly of débris, whether it be of preëxistent rocks or of the hard parts of organisms. The rocks composing the groups have been deposited by the ordinary processes of sedimentation. Outside of these so-called clastic groups are left to be separately provided for the various rocks which have been termed collectively the crystalline schists, and which, in the paper referred to, are embraced under

* This is the signification of the French; but in the original English MS., from which the French translation was made for publication, this clause reads, "are presumptively world-wide in distribution."

† Translated from the French of the original article, op. cit., p. 15.

the general term of "non-eruptive crystallines." These are set off by themselves collectively because, while it is admitted that the larger part of them are of an age greater than those of the recognized clastic groups, it is desired to avoid for the present the still disputed points: (1) as to whether some of them are not altered clastic rocks of later geological age; and (2) as to whether those which unquestionably belong below the base of the ordinarily recognized Palæozoic groups are, or are not, divisible into members of a taxonomic rank equal with that of those groups.

It is with this latter question, or rather with a portion of it, that the present essay concerns itself. I say a portion of it because the general question as to what groups, if any, we should recognize among the pre-Cambrian rocks would be quite too broad a one for the space that can now be occupied. Not to speak of other points that would have to be considered, the answer to this general question would involve, in the first place, a discussion as to the separate existence, and taxonomic relations of the so-called Keweenaw Series of Lake Superior. My design is then merely to inquire if there can be carved off of the upper portion of the great complex which has been called Archæan, a series of *Huronian* rocks; a series entitled—by structural and genetic separateness, by clastic origin, by largeness of volume, and by the being made up of subordinate divisions of the formation rank—to the rank of a group, i. e., to a rank equal in classificatory value to the Cambrian, Silurian, etc.

II. The term *Huronian* seems first to have been used in a publication prepared for the Paris Exposition of 1855, by Sir Wm. Logan and Dr. T. S. Hunt, on part of the Geological Survey of Canada, and entitled "Esquisse Géologique du Canada." As used in this volume, however, the term has but a very vague and unsatisfactory signification. To begin with, it is used only as a synonym of *Cambrian*, and is not made to apply especially to any one individual or typical area, but to embrace vaguely defined series of rocks occurring in various wholly separated areas on Lakes Superior and Huron, which series may or may not be geologically equivalents of one another so far as any evidence presented goes to show. Moreover, the term is made to cover also the great and wholly distinct succession afterwards separated out as the Copper-Bearing or Keweenaw Series.

The term Huronian was afterwards used in various reports of the Canada Survey, with a somewhat changing signification, until, in 1863, Sir William Logan gave, in the Geology of Canada, a thoroughly definite account of the series, including

all information to date. With this description he gives also a detailed map and sections of "The Huronian Rocks" on the north shore of Lake Huron, between the St. Mary's and Missisagui rivers. This particular series Murray had described as early as 1848, as "a set of regularly stratified masses, consisting of quartz rocks or altered sandstones, conglomerates, slates and limestones, interstratified with beds of greenstone." Although both Logan and Murray extended the name Huronian to other rocks in the Lake Superior region this series was the only one so covered that was ever studied and mapped in any thorough manner, while the correlation of the other so-called Huronian areas with this one rested always on a pretty slender foundation. If then we seek—as we must do—for a type series with which to start a study of the so-called Huronian, we can find it only in this Lake Huron Series. This seems indeed to have done duty more or less definitely as such a type in the writings of European and American geologists for five and twenty years; although, most unfortunately, of the many who have made use of the name Huronian, only a very few have studied these rocks on the ground, in any such manner as to warrant the opinions they have so freely expressed.

Evidently our inquiry should begin with a study of this type series of rocks. Is this series, in its nature, volume and subordinate divisions, entitled to the rank of a clastic group? Do its structural relations and lithological contrasts with the great mass of the Archæan, with which it is in direct contact, indicate a chronological separateness? In attempting an answer to these questions, I make use not only of the facts summarized in Logan's descriptions and upon his map, but also of the results of my own observations extended during two seasons, not only in the area especially mapped as Huronian on the plate to which I have already referred, but also over a large contiguous area further to the eastward, which has been mapped as Huronian on the recent general maps of the Canadian Survey.

III. Briefly, then, that series of rocks, which is especially mapped by Logan on the plate above referred to, and which we may properly designate as the type or original Huronian, may be described as a great succession of quartzite layers, including a subordinate quantity of greywackes, a much smaller proportion of "limestone and chert" and numerous eruptive diabasic greenstones; the latter occurring both in dyke and sheet form. In the main the series is but very gently bowed. Only rarely the inclinations of the strata reach twenty degrees, while large areas occur, particularly in the interior and away from the lake shore, where the strata are not visibly removed from horizontality, the whole appearance of the topography in

such cases recalling strongly many regions of later horizontal strata, for instance that of the upper Mississippi valley.

According to Murray and Logan*—for whose painstaking accuracy and general geological insight I acquired the greatest respect while passing over the region, with their map and descriptions in hand—the series is made up of the following succession of strata, in ascending order, viz:†

Fig. 1. Section of the original or type Huronian, showing its relation to the pre-Huronian crystallines, Lake Huron. Scale, 10 miles to the inch. Reduced from Logan's section. *a–b*, Laurentian; *b–c*, Huronian; *d*, Cambrian and Lower Silurian.

		Thickness in feet.
1.	Gray quartzite	500
2.	"Chloritic and epidotic slates interstratified with trap-like beds"	2000
3.	White quartzite, often conglomeratic	1000
4.	"Slate-conglomerate, composed of pebbles of gneiss and syenite, held in an argillaceous cement of a gray to greenish color"	1280
5.	Limestone, thin-banded, often argillaceous	300
6.	"Slate-conglomerate," like No. 4	3000
7.	Red quartzite	2300
8.	"Red jasper-conglomerate;" a quartzite with frequent red jasper pebbles	2150
9.	White quartzite	2970
10.	Yellow chert and limestone	400
11.	White quartzite	1500
12.	Yellow chert and impure limestone	200
13.	White quartzite	400
	Total	18,000

* In the discussion which followed the reading of this paper, the point was made that I gave too much credit to Logan and too little to Murray, in the matter of the working out of the original or type Huronian series. My wish, of course, is to do exactly right in such a matter; but it is very difficult for one not familiar with the inside history of the Canadian Survey, particularly after the lapse of so many years, to adjust the credits correctly. In the Geology of Canada of 1863, which must serve as the source of information, the description of the series is all in Logan's own words, plainly. He also speaks distinctly of having examined this region in person (Preface, p. v); while Mr. Murray's examinations are said, in a general way only, to have extended over "Western Canada." In the atlas accompanying the Geology of Canada, however, it is said that the detailed map of the Huronian (Plate III, of the Atlas), to which reference is made above, is "chiefly from the surveys of Mr. Alex. Murray." The sections accompanying this map were drawn by Logan himself. (See Preface to Atlas, p. iv.) It would seem that Logan, after examining the ground himself to some extent, made use of Murray's more detailed studies also, from which to construct the map and sections himself, and to prepare the general description.

† Abbreviated from Logan's detailed section given in the Geology of Canada, 1863, pp. 56–58.

The thicknesses of the interbedded eruptives are not separately given, but their subtraction would not seriously affect these figures, except in the case of division No. 2, which, as subsequently shown, is very largely composed of diabase sheets. Placing together the several kinds of material composing Logan's section, without reference to stratigraphical order and without making any correction for included eruptives, the series is seen to be composed as follows: quartzite, 10,820 feet; "slate conglomerate," 4280 feet; "chloritic and epidotic slates and trap" 2000 feet: limestone and chert, 900 feet=18,000 feet. But a much more accurate conception of the relative proportions of the different kinds of rocks which constitute this series may be reached by making several important modifications of this statement. In the first place my own examinations of the ground, while they have served to convince me of the general correctness of Logan's section, have shown me that considerable portions of his "slate conglomerate" members are made up of quartzites, the remainder of these members being composed of dark-colored fragmental rocks, to which the name of greywacke more nearly applies than any other given in the books. Moreover, that portion of the series designated by Logan as "chloritic slates and traps" (No. 2), I have found by a study on the ground, and of a number of thin sections, to be mainly composed of a succession of diabase-sheets, along with which is a little interleaved fragmental material, perhaps partly of the nature of volcanic ash, but with which there is also some true sedimentary material. Taking these facts into account, and remembering also the interleaving of greenstone sheets at different horizons in the series, I estimate the whole succession to be about two-thirds quartzite, one-sixth greywacke, and one-twentieth "lime-stone and chert," the remainder being chiefly composed of eruptive material.

Of these rocks the *quartzites* are all no more nor less than indurated sandstones, without prominent schistose structure. The induration—which varies so greatly in degree that some of these rocks are almost loose sandstones, while others are completely vitrified quartzites, the two extremes occurring at times in close association with one another—is always due to the presence of an infiltrated silica. This infiltrated material occurs partly in the shape of a minute mosaic between the plainly recognizable rolled fragments of quartz, of which the rock is mainly composed; but is for the most part in the shape of enlargements or secondary growths to these fragments. This process of enlargement, which I have described and illustrated freely elsewhere, is one which, as I have been able to show, has affected fragmental quartzose rocks of all ages, from the most recent to the most ancient. Every stage in the development

of the process is recognizable among these ancient quartzites, as well as in the similar rocks of more recent formations. Even in the extent to which this indurating process has been carried on, the Huronian quartzites do not differ so remarkably from many sandstones of much later periods, like which they show also the ripple and other markings so characteristic of water-deposited sand.

The dark-colored fragmental rocks of this series, which I have embraced under the general head of *greywacke*, and which vary in coarseness of grain from aphanitic, slaty kinds to rather coarse grits, and are often dotted with pebbles and bowlders of granite and gneiss, are, equally with the quartzites, genuine clastic rocks, often differing in no respect from similar rocks found in various portions of the world, and at various horizons in the Palæozoic series, where they are found to be frequently highly fossiliferous. Indeed, these Lake Huron greywackes have on the whole undergone much less alteration than many fossiliferous rocks of a similar nature. Those of the north shore of Lake Huron are very regularly stratified, gray to black, often ripple-marked, compact aggregates of rounded to subangular mineral fragments, which include, besides pieces of quartz, particles of various other minerals, particularly of feldspars. Often the fragments are recognizable as particles of rocks, the disintegration having left the different mineral ingredients attached to one another. The thin sections of all of these greywackes show that their indurated condition is due partly, perhaps mainly, to a secondary deposition of interstitial quartz, entirely analogous to that just described as characteristic of the quartzites of the series; but that it is also due in part to a very general development of chloritic material from the feldspar fragments, to the presence of which chloritic ingredient the dark color of the rock is mainly due.

Limestone is made by Logan to constitute more or less of three numbers of his succession (Nos. 5, 10 and 12; respectively, 300, 400 and 200 feet in thickness). The lowest one of these three bands, which occurs in the lower half of the series, and is finely exposed along the shore of Lake Huron about two miles west of Bruce Mine Bay, is a thin-bedded, dark gray, often brown-weathering, compact and earthy-looking limestone. The very striking and regular thin lamination, which is brought out with the greatest prominence on weathered surfaces, the more impure laminæ being left projecting in little ridges above the more purely calcareous ones, seems to place the sedimentary origin of this rock beyond a question. This conclusion is borne out very emphatically by the appearance of the thin sections, which show distinctly a fragmental material mingled with the felted mass of minutely crystalline car-

bonate, the whole appearance of the section differing in no respect from sections I have examined of Palæozoic limestones. Not that it seems to me necessary to believe in a direct organic origin for the carbonate of lime contained. The whole process may have been a combination of the mechanical and chemical kinds of sedimentation such as we find exemplified in the clayey beds of the Coal Measures carrying carbonate of iron, and at various other geological horizons. The two other lime-bearing members of the series as marked by Logan are spoken of by him as very largely cherty, and as including here and there sandstone layers. In our own examination of these beds, made chiefly in the back country between Echo Lake and Garden River, it appeared to us that the cherty material predominated very largely over the calcareous. In this region the cherty layers are almost entirely horizontal, the whole appearance of the bluff sides of the exposures being that ordinarily presented by the horizontal formations, as, for instance, in the upper Mississippi valley. This horizontality, taken along with the very thin lamination of these rocks, and the presence of more or less distinctly detrital material, as is observable on the larger scale as well as microscopically, serves to place beyond question the sedimentary origin of these layers. Often these cherty beds are quite ferruginous, and at the same time brecciated, in which case they parallel very closely occurrences in the Marquette and Penokee iron regions on the south side of Lake Superior, and are not unlike occurrences among some of the later fossiliferous formations. Whatever may be true, then, of the origin of those great masses of coarsely crystalline limestone which are associated with the ancient gneisses, no doubt can be entertained of the sedimentary origin of these limestones of the original Huronian. Moreover, they have undergone since their first deposition changes no greater than are attributable to the action of infiltrating waters, or than those often found among the Palæozoic limestones.

Of the four principal kinds of rocks which constitute the series according to the estimate I have given above, there remain to be mentioned only those crystalline rocks which I have spoken of collectively under the convenient term of *greenstone*. Of these I need now say only that they are mainly diabases in no important respect different from eruptive diabases at various other horizons, that they are mainly non-schistose, and that they present no sign whatever of gradation into the adjoining sedimentary strata.

Thus the first part of our inquiry, with regard to the original or type Huronian is answered in the affirmative. Intrinsically, it is fully entitled to the group rank. Its detrital or clastic origin; its largeness of volume; its inclusion of a number of

subordinate strata—each entitled by its thickness and petrographical distinctness to be classed with any of the "formational" subdivisions of any of the Palæozoic groups—combine to give it this position. But it remains to be considered whether there is equally strong warrant for believing this series to be structurally, and consequently chronologically, separable from the adjoining portions of the so-called Archæan. Is it not possible that we are merely setting off arbitrarily a set of rocks which is really only part and parcel of the whole great Archæan complex, and is not separable by any genuine line of demarkation?

Before attempting to reply to this part of the problem it will be well to understand what sort of evidence that must be whose production will establish a degree of chronological separateness sufficient to warrant the ranking of this original Huronian as a Group. Such a degree of separateness, then, can only be established when we have in hand good reason for a belief in the subjection of the underlying rocks, as a land surface, to a long-continued atmospheric erosion, before the deposition upon them of the detrital series whose group rank it is desired to establish. In the cases of discordances between groups higher in the geological scale than that we are now considering, the rocks *below* as well as those *above* the discordance are of unquestioned sedimentary origin; so that in such cases we have indicated two periods of submergence, separated from one another by one of disturbance, emergence and erosion. But this accepted aqueous origin for the lower rocks is not essential. We may have equally good reason for a belief in a lengthy intervening period when the lower rocks are crystalline schists, as to whose origin there may be question, or sometimes even when they are eruptives. In the former case the foliation, schistose structure, and general crystalline character of the lower rocks, when contrasted with the absence of such characteristics in the higher, indicate the subjection of the former to long-continued and deep-seated processes of alteration, whatever the first origin, and consequently to profound erosion, before the deposition upon them of the overlying detritals. Fragments of the lower crystalline rocks occurring in the higher detritals, particularly at the contacts of the two, serve greatly to strengthen such a conclusion; since these must be taken as a final demonstration of the production of the schistosity and foliation prior to the long-continued period of denudation which in turn must have been accomplished before the detrital deposition began. Somewhat similar reasoning will serve even if the lower rocks are of non-schistose, plutonic kinds ("tiefen Gesteine" of Rosenbusch), since these must have cooled at great depths, and must have been deeply denuded before the

masses of the different kinds of eruptives could be truncated or yield fragments to detrital deposits. In case the basement rocks are a combination of plutonic eruptives with crystalline schists, additional proof may be found in the fact that the eruptives intersect the schists, while they are truncated by the overlying fragmental rocks, to which also they have yielded fragments.

Now all of this evidence is forthcoming in the original Huronian region, and in the clearest and most unequivocal manner. The Huronian series is detrital and non-schistose; the underlying rocks are crystalline schists (mainly mica-schist), gneiss and granite; the mica-schists being without remaining fragmental texture, though at times banded in such a manner as to render an original fragmental condition very probable. The upper rocks are not intersected by the granite where the two come in contact; the lower schists and gneiss are deeply invaded by it in great bosses, in irregular masses of smaller size, and in an intricate net-work of veins; as may be seen most beautifully eastward from Algoma Mills, on the Lake Huron coast, and along the line of that branch of the Canadian Pacific Railway which extends from Algoma Mills to Sudbury on the main line.

Fragments of the older rocks occur in the detrital series at various horizons, but in most especial beauty at the contacts of the two series. These latter conglomerates are true *basal* conglomerates, whose asserted absence certain geologists* have urged with much emphasis as an argument against the existence of any separate Huronian series; i. e., separate from the remainder of the great Archæan complex. I may therefore not improperly enlarge somewhat on their actual occurrence. Probably the handsomest instance is that at the contact of Logan's basal member of the series, on the Lake Huron coast, about three miles east of the mouth of Thessalon River. From this point

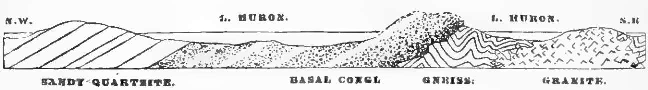


FIG. 2. Section about three miles east of the mouth of Thessalon River, Lake Huron, showing conglomerate at the base of the Huronian. Scale, 400 feet to the inch.

eastward the older gneiss, granite, etc., spread along the coast to Algoma Mills, and beyond. The contact is best seen in a group of small islands lying close to the mainland. These islands are moutonnéed to a very high degree, and are largely bare, so that the rocks are finely displayed. The figure is a section through three of these islands, the middle one of which shows the granite and gneiss at one end, and, resting

* J. D. Whitney and M. E. Wadsworth, in the "Azoic System," pp. 556, 557.

upon these and filling the irregularities of the original surface, the conglomerate rock, which dips some thirty degrees toward the northwest. The stratiform arrangement of the conglomerate is finely brought out by the interleaving of sandy layers, in which the pebbles are wanting, or nearly so. The sub-angular to angular fragments of the conglomerate, ranging in size from a fine detritus to bowlders two feet in length, are confusedly heaped together in the vicinity of the immediate contact; but further away show a tendency to arrangement in bands. They are mainly composed, in order of relative abundance, of a gray biotite gneiss or gneissoid granite, of red granite (including several varieties) and of dark-colored schists. The matrix, which is at times almost or wholly excluded by the bowlders, is mainly a fine detritus of the same nature as the fragments, the constituent minerals of the original rocks becoming more thoroughly separated from one another as the particles are finer. This finer detritus becomes more quartzose and arenaceous in the interleaved, non-conglomeratic layers, particularly as one passes away from the immediate contact. In these portions also there is present more or less of a kaolinic or sericitic ingredient resulting from the decay of the feldspathic constituents. Finally, invading the matrix very irregularly, at times giving it the appearance of a completely vitreous quartzite, and again leaving it very arenaceous in texture, is a siliceous cement, which has partly separated out as a finely interlocking quartz but often has divided itself off more or less thoroughly as enlargements of the quartz fragments. Upwards the conglomerate graduates into an arenaceous quartzite.

Closely analogous phenomena are to be seen at the contacts of these two sets of rocks displayed at three points on the line of that branch of the Canadian Pacific which runs from Algoma Mills to Sudbury on the main line, and particularly in the vicinity of the mouth of Serpent River. The pebbles and bowlders at these contacts are of all sizes up to two or three feet in diameter, and include granite, gneiss and mica-schist. It should be added that fragments of gneiss and granite are met with at various horizons through the Huronian series, often in considerable abundance in one place, while large parts of the series are composed of a little assorted granitic and gneissic detritus. These pebbles, and the finer gneissic detritus, though not at the base of the series, furnish strong evidence of the relatively great antiquity of the rocks which yielded them.

Thus the structural relations of the original or typical Huronian series to the older schists are such as to render abundantly evident its entire chronological separateness from them; and the second part also of our inquiry is answered in the affirmative.

Returning now to the classification of rocks and the characterization of the Group, quoted at the beginning of this paper, it will be seen that under this classification the Huronian can only be a group, since—(1) *it is essentially non-crystalline*, and therefore not to be placed with the non-eruptive crystallines, from which, moreover, it is structurally wholly separate; (2) *it is truly clastic and sedimentary*, and therefore must be included with the clastic groups, because these "comprise all the formations of known clastic origin;" and (3) *it has an immense volume*—a volume not only comparable with those of the ordinarily recognized fossiliferous groups, but in excess of the volumes of many of them. It cannot be a formation, being made up of formations. The classification then leaves us no choice but to call it a group.

The definition quoted demands, it is true, some other characters for the group in addition to those just mentioned, but since the latter are restricted by it to the true group, it is evident that in the original Huronian we are dealing with one of these groups, or that the definition is defective. This point I return to in the closing section of my paper, and may therefore pass it over for the present, merely remarking by the way that the question which has been raised by some, as to whether the Lake Huron Huronian may not be the equivalent of some group elsewhere recognized as fossiliferous, say the Cambrian or the Silurian, is hardly worthy of discussion. Here, in the typical region itself, the Upper Cambrian sandstone (Potsdam) may be seen crossing the immensely denuded surface and decapitated folds of the Huronian; so that to include the Huronian even in the Cambrian would require us to stretch that term over one of the greatest, if not *the* greatest, of the structural gaps in the whole geological column. Moreover, there is every reason to believe that the great Keweenaw Series of Keweenaw Point belongs to this interval, though by no means filling it. This series, on the south shore of Lake Superior, lies unconformably beneath the same Cambrian sandstone which traverses the edges of the Lake Huron Huronian, while at the same time unconformable to rocks beneath it whose equivalence with the original Huronian there is every reason to accept, as is subsequently maintained in this paper.

[To be continued.]

ART. XXV.—*Ovibos cavifrons from the Loess of Iowa;* by W. J. McGEE.

A REMARKABLY perfect specimen of the extinct musk ox of North America has recently fallen into the hands of Prof. S. Calvin, of the Iowa State University. It was found in the loess of the Missouri River at Council Bluffs, Iowa, at a point 12 feet below the surface and 130 feet above the river. The bones collected comprise the larger part of the cranium with horn cores attached and some of the molars in place, about half of the lower jaw, the atlas, a femur, and a number of other bones in more or less fragmentary condition. The material has been placed in the cabinet of the State University at Iowa City.

This animal was introduced to science in this country by Dekay in 1828 under the name *Bos Pallassi;** it was more thoroughly investigated in 1852,† and the genus and species characterized in 1853,‡ by Leidy, under the provisional name *Bootherium cavifrons;* and in 1869 it was by the same author transferred to the genus *Ovibos.*§ At that time its remains were known from Fort Gibson, I. T., St. Louis, New Madrid, and Benton County, Mo., Trumbull County, Ohio, Big Bone Lick, Ky., and (probably) "the frozen cliffs of Eschscholtz Bay." The New Madrid specimen, which was the subject of Dekay's description, was thrown out of one of the earth-fissures formed during the great earthquake of 1811–13; and the adhering matrix indicated that it had been imbedded in pebbly and sandy clay containing considerable quantities of lignitized wood. The Fort Gibson specimen, which was Leidy's type, was reported to have come from a gravelly bluff of the Arkansas River, but had long been used as a seat "in the hut of an Indian."

The Council Bluffs discovery is significant in that it adds an important link to the already strong chain of evidence as to the climate of the loess period. Leidy expresses the opinion that *cavifrons* was clothed with a long fleece like that of its modern congener; and the occurrence of its remains in the loess is thus indicative of low temperature during the accumulation of this phase of the glacial deposits. The immediate associates of the Council Bluffs individual included the elephant and mastodon, at least one small rodent, paleolithic man according to Aughey,‖

* Ann. Lyc. Nat. Hist. N. Y., vol. ii, 280–91.

† Proc. Acad. Nat. Sci. Phil., vol. vi, 71.

‡ "Memoir on the Extinct Species of the American Ox," Smithsonian Contributions, vol. v, 12–17.

§ "The Extinct Mammalian Fauna of Dakota and Nebraska," etc., Journ. Acad. Nat. Sci. Phil., 2d ser., vol. vii, 374–5.

‖ Hayden's Ann. Rep. U. S. Geol. and Geog. Surv., for 1874, 254–5.

and several pulmoniferous mollusca, which are here of normal size and character, while at Des Moines, a hundred miles to the eastward, they are depauperate,* presumptively by reason of the frigid climate of that period. Under about the same latitude on the Mississippi the loess fauna includes the elephant† and the woodland reindeer (*Rangifer caribou*), or some closely allied species for which the alternative name *Cervus muscatinensis* has been suggested by Leidy,‡ together with several terrestrial and fresh water mollusca only slightly, if at all, depauperate; but within fifty miles to the northward, in Clinton County, Iowa, the loess shells are notably depauperate, and fifty miles further, in Dubuque County, they are exceedingly rare and reduced to a half or third, or even a fourth, of their normal linear dimensions.

This testimony of the fauna as to the temperature of the loess period is corroborated by that of the deposits themselves. At Des Moines the loess graduates downward into, and is moreover overlaid by, glacial drift; midway between Des Moines and the Mississippi River the loess merges into the underlying drift so imperceptibly that no line of demarkation can be drawn between them, and it is evident that the two represent merely different phases of the same deposit; much of the loess of eastern Iowa unquestionably consists of the mud of glacial streams, laid down in ice-bound lakes;§ and the Missouri River loess has been shown by N. H. Winchell to graduate into morainal drift in southwestern Minnesota,‖ just as is the case in southeastern Iowa.

It is noteworthy that while the Council Bluffs specimen comes from well within the glaciated area and the Big Bone Lick specimen from near its margin, the Missouri and Indian Territory specimens are from localities some three degrees beyond the limits of that area; and, although the data are too meagre to justify final conclusion, it may be inferred that the glacial refrigeration forced the Arctic fauna about that far beyond the ice margin, and that it was felt even farther southward. This inference is in harmony with the results of recent work in eastern United States. During the earlier epoch of Quaternary cold, the middle Atlantic slope was submerged to a depth of over three hundred feet, and its rivers—the Delaware, the Susquehanna, the Patapsco, the Potomac, the Rappahannock, the James, the Appomattox, and the Roanoke—built deltas at their embouchures into the expanded Atlantic along the inland margin of the Coastal Plain of to-day. A conspicu-

* This Journal, III, vol. xxiv, 1882, 215–219.

† Proc. Davenport Acad. Nat. Sci., vol. i, 1876, 196–9.

‡ Proc. Acad. Nat. Sci. Phil., vol. xxxi, 32–3.

§ Trans. Iowa State Hort. Soc. for 1883, vol. xviii, 328–39.

‖ Sixth Ann. Rep. Geol. and Nat. Hist. Surv. Minn., 1877, 104–6.

ous element in these deltas consists of the bowlders floated down in the ice floes of winter and spring, just as considerable masses of gneiss are now carried into the estuarine portions of the rivers by every spring freshet. Now in the Quaternary delta of the Susquehanna, the bowlders are at least fifty times as large as those brought down in the ice-blocks of the present; in the Patapsco and Potomac deltas, the Quaternary bowlders are twenty times as large as those of to-day; along the Rappahannock, the ancient bowlders are ten times as large as the modern; on the James and Appomattox, the old are five times larger than the new; and on the Roanoke the bowlders of the delta are twice or thrice as large as those of the modern alluvium. It would appear, accordingly, that the Quaternary refrigeration here extended as much as, yet but little more than, three or four degrees beyond the ice margin. The inference is fairly harmonious, too, with the conclusions already reached concerning the Quaternary climate of western United States. King,* Gilbert,† and Russell‡ have indeed shown that the refrigeration of the glacial time was felt fully ten degrees beyond the Cordilleran ice-margin; but in this region the effects of refrigeration were unquestionably cumulative, and the chief climatal effect was increased humidity and consequent expansion of the outletless lakes of the Great Basin, with comparatively slight increase in the local glaciers of the Sierras and on the peaks of the Wasatch, and (probably) with little diminution in the mean temperature.

The recent discovery is significant, also, in that it greatly extends the applicability of *cavifrons* as a criterion for correlating deposits of widely diverse genesis in widely separate localities. In their classic report on the Mississippi River, Humphreys and Abbot show that the so-called alluvium of the lower portion of that river consists mainly of a heavy deposit of hard blue or drab clay containing abundant carbonaceous matter, generally covered by a slight veneer of modern alluvium, and concluded that the deposit was formed "long antecedent to the present epoch."§ Hilgard designated this blue clay deposit Port Hudson,‖ observed that it was intercalated between the loess and the Orange Sand, and inferred that it was laid down during a period of submergence of the lower Mississippi region probably coincident with some later stage of the glacial epoch; and he specifically supported the opinion of the engineers as to its

* U. S. Geol. Expl. 40th par., vol. i. Systematic Geology, 1878, 461, analytic map v, 480–529.

† 2d Ann. Rep. U. S. Geol. Survey, 1882, 186–189.

‡ Geol. Hist. of Lake Lahontan, Monograph U. S. Geol. Survey, vol. xi, 261; and elsewhere.

§ Physics and Hydraulics of the Miss. River, 1876, 57–58, 91–95.

‖ This Journal, II, vol. xlviii, 1869, 332.

antiquity and distinctness from the alluvium proper.* Now the New Madrid specimen appears to have come from the Port Hudson beds; and the Fort Gibson specimen was obtained from a puzzling superficial deposit found in Missouri, southern Kansas, Indian Territory, Eastern Texas, and Arkansas, which is conspicuous along the water-ways but attenuates and frequently disappears over the higher lands, and which seems to be a slack-water deposit laid down in the waterways of the region during the Port Hudson submergence. The paleontologic correlation is therefore perfectly consonant with the physical, and the two lines of evidence are cumulative. The evidence of the fossils is of exceptional value, too, when, like *Ovibos* and *Rangifer*, they represent an arctic fauna; for not only are vertebrates the most sensitive time indicators, by reason of the evanescence of types, as shown by Marsh, but when the remains of arctic animals are found in temperate latitudes it is manifest that they indicate only a temporary incursion of the fauna, and therefore represent but a small portion of the period covered by the phylogeny of the species.

ART. XXVI.—*On the Chemical Composition of Howlite, with a note on the Gooch method for the determination of boracic acid;* by S. L. PENFIELD and E. S. SPERRY.

THIS interesting mineral was first identified as a new species by Prof. Henry How,† of Windsor, Nova Scotia, who named it silicoborocalcite, assigning to it the composition $2CaO.SiO_2 + 2(CaO_2.BO_3.HO) + BO_3.3HO$, written in the old system and in the form suggested by Prof. How. He described it as occurring in dense, chalk-like nodules in the gypsum beds at Brookfield, near Windsor, N. S. In later papers‡ he mentions its occurring in four distinct localities near Windsor, the nodules being sometimes as large as a man's head and composed of minute scaly and silky crystals. The name howlite was substituted for silicoborocalcite by Prof. J. D. Dana and used by him in the fifth edition of his System of Mineralogy.

The specimen which we have examined was collected in the gypsum quarries at Windsor, N. S., by Mr. Charles G. Rupert, of Minneapolis, Minn., who generously presented it to the mineralogical department for investigation. It consisted of an egg-shaped nodule about one and one-half inches in its greatest diameter, embedded in massive gypsum. The nodule was composed of intergrown microscopic needles which under the

* This Journal, III, vol. ii, 1871, 402.
† Phil. Mag., IV, xxxv, p. 32.
‡ Phil. Mag., IV, xxxvii, 270 and xxxix, 278.

microscope were resolved into flattened prismatic forms, having somewhat the shape of thin stilbite crystals, the largest 0·23 × 0·27 mm., usually broken at the extremities but occasionally terminated by two dome faces. In polarized light they showed parallel extinction, brilliant polarization colors, red and yellow of the first order, according to the thickness of the crystal, the longer axis being the axis of least elasticity. In convergent light an obtuse bisectrix was very indistinctly seen, the plane of the optic axes being at right angles to the longer axis of the crystal. The crystallization is therefore probably orthorhombic. Owing to the slight solubility of the mineral in water its specific gravity was taken in alcohol and found to be 2·59 referred to water. A sample was taken for analysis by breaking into the nodule and carefully freeing from adhering gypsum by hand picking, but it was impossible to obtain the borate perfectly pure, a little SO_3 being found on analysis which undoubtedly resulted from adhering gypsum. The results of analysis of the air-dry powder are as follows:

	I.	II.	Mean.
SiO_2	14·65	14·74	14·70
B_2O_3	42·68	42·70	42·69
CaO	28·22	28·19	28·20
Na_2O	·55	·47	·51
K_2O		·12	·12
H_2O	12·01	11·94	11·97
SO_3	1·93	2·10	2·01
			100·20

Below the results are given after deducting 4·32 per cent of gypsum corresponding to 2·01 per cent of SO_3, and calculating to 100·00 per cent together with the analysis of How and the theoretical percentages derived from our ratio.

		Ratio.		How.	Calculated for $H_5Ca_2B_5SiO_{14}$.
SiO_2	15·33	·255	2·00	15·25	15·31
B_2O_3	44·52	·636	5·00	[44·22]	44·65
CaO	27·94	·498		28·65	28·56
Na_2O	·53	·008	·507 3·99		
K_2O	·13	·001			
H_2O	11·55	·641	5·04	11·84	11·48
	100·00			100·00	100·00

The ratio of $SiO_2 : B_2O_3 : CaO : H_2O = 2 : 5 : 4 : 5$ very closely, with a small part of the CaO replaced by Na_2O and K_2O. This is exactly the ratio obtained by Prof. How, but the analysis is of importance as proving the identity of this curious boro-silicate as a distinct species, the original analysis having been made on dense chalk-like varieties and the most important con-

stituent, B_2O_3, being determined by difference. The air-dry powder of the mineral lost water slowly at 100° C. but soon came to a constant weight at 150° C. losing 0·83 per cent, the mineral suffering no further loss by heating to 360°. The loss of 0·83 per cent corresponds closely to 0·90 per cent, the amount of water contained in the 4·32 per cent of gypsum which the analyzed portion contained. Thus the loss of water at 150° C. as well as the SO_3 determination and the occurrence of the nodule in massive gypsum suggest that there was a slight impurity of gypsum in the material which was analyzed. The fact that the mineral does not part with its water at 360° C. indicates that the hydrogen is very firmly united in the molecule, probably as hydroxyl. The mineral is therefore a very acid silico-borate and its formula may be written $H_6Ca_2B_5SiO_{14}$, differing essentially from the more common silico-borates of calcium, datolite and danburite, in containing much less silica and more boracic acid, causing the mineral to be classified more naturally with the borates than with the silicates.

On igniting the mineral in a closed tube water is given off which reacts strongly for boracic acid with tumeric paper; the water in the above analysis was therefore obtained by ignition and absorption in a chloride of calcium tube. The boracic acid was determined by the admirable method suggested by Prof. F. A. Gooch.* The other constituents were determined by the usual methods.

2. *Note on the Gooch method for the determination of boracic acid.*

Before commencing the above analysis we carefully reviewed the method described by Prof. Gooch,† making a number of determinations of B_2O_3 in borax in order to become fully acquainted with the method. The distilling apparatus described by him proved very satisfactory. The boracic acid in our experiments was set free by nitric acid, distilled over with methyl alcohol and evaporated with a weighed quantity of ignited calcium oxide. Without the use of very large platinum crucibles the evaporation of the boric ether with slaked lime is attended with some difficulty. The calcium borate together with the excess of lime form as a thick crystalline precipitate at the bottom of the crucible and if the methyl alcohol boils during the evaporation some of the precipitate will be carried mechanically out of the crucible; then too the very strong ignition of the CaO necessary to bring it to a constant weight is not so readily accomplished if the crucibles are very large. The following method was found to give very good satisfaction and can be used by any one having an ordinary sized platinum crucible and preferably a platinum dish.

* Am. Chem. Journal, ix, p. 23. † Loc. cit.

The lime after being ignited to a constant weight and slaked is transferred to a large platinum dish and warmed with water till it becomes of a milky consistency; it is not necessary to remove all the lime from the crucible, the latter being put away and used later on. Strong ammonia is poured into the receiving flask of the distilling apparatus described by Gooch, and after conducting the distillation as directed the contents of the receiver are poured into the platinum dish containing the slaked lime, water being freely used in rinsing out the receiver. The dish is then placed on a triangle over the water bath or otherwise gently heated till the volatile products, methyl alcohol and ammonia, are driven off, which by boiling might cause mechanical loss. When these are removed the contents of the dish can be evaporated to dryness. The dried calcium borate and the excess of lime are now transferred to the crucible in which the lime was weighed, this being easily accomplished by moistening the contents of the dish with water and shoving the bulk of the precipitate into the crucible with a spatula, by rinsing with a little water and by using a rubber on the end of a glass rod all but a very little of the borate and lime can be transferred to the crucible; that which sticks too firmly to the dish can be dissolved in one or two drops of dilute nitric acid which is brought in contact with all parts of the dish with the rubber; the solution is then transferred and rinsed into the crucible. The transfer and washing can readily be made by using not over 30 cc. of water which can be contained in an ordinary student's crucible. The evaporation from this point goes on very simply, the borate drying out nicely on the water-bath. By placing the platinum crucible in a large porcelain one and gradually raising the heat to strong ignition the borate may be further dried out without any danger of snapping. The residue is finally ignited over the blast lamp till a constant weight is obtained.

In slaking the lime we have found it convenient not to add the water directly to the ignited lime, causing danger from excessive heating and mechanical loss, but to place the open crucible on a watch glass containing water and covered with a bell jar: in this way the lime soon slakes and in case of special hurry hot water may be placed in the watch-glass from time to time so that the atmosphere under the bell jar will be thoroughly saturated; in this way the lime will become so thoroughly slaked in one or two hours that there will be no danger of excessive heating on further addition of water.

The following results were obtained using in all cases about one gram of crystallized borax and one gram of lime: B_2O_3 in borax 36·55, 36·42, 36·58, 36·64, calculated 36·64 per cent.

Mineralogical Laboratory,
Sheffield Scientific School, April 14, 1887.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On a Vapor-calorimeter.*—BUNSEN has described a new calorimeter based on the principle, first employed by Joly, of using the condensation of saturated water-vapor of constant temperature as the calorimetric measure. Having carefully studied the problem, the author has confirmed the practicability of the method, and has constructed an instrument in which the principal difficulties are entirely overcome. The body whose specific heat is desired is placed in a platinum basket and suspended in the vapor of boiling water. The water which is condensed during the heating of the body, is retained in the basket and can be weighed provided the weighing is done in the vapor. From the weight thus obtained, since the latent heat of condensation of water-vapor is known, the amount of heat absorbed by the body in raising its temperature through the given number of degrees may be calculated.—*Ann. Phys. Chem.* II, xxxi, 1; *Ber. Berl. Chem. Ges.*, xx, 275 (Ref.), May, 1887. G. F. B.

2. *On the density of liquid Methane, Oxygen and Nitrogen.*—By the use of his apparatus, OLSZEWSKY has been able to obtain 13 to 15 c.c. of any desired gas in the liquid condition, cooled by boiling ethylene and liquefied by pressure. The liquid is collected in a double glass tube, and when freed from external pressure, the exterior layer evaporates first under the influence of the relatively warmer ethylene, while about 4 or 5 c.c. of the substance remains in the inner tube cooled in this way to its own boiling point. This portion of liquid is thoroughly protected against the access of heat, and can evaporate therefore only with proportionate slowness. At a given moment its volume may be read off on a scale engraved on the glass tube in which it is contained. Its mass may easily be determined from the amount of gas given by its evaporation; and from these data the density of the liquid is readily calculated. The densities of methane, of oxygen, and of nitrogen thus found are as follows, at the temperature of their boiling points :

	Density.	Boiling point.
Methane,	0·415	−164·0°
Oxygen,	1·124	−181·4°
Nitrogen,	0·885	−194·4°

—*Ann. Phys. Chem.* II, xxxi, 58; *Ber. Berl. Chem. Ges.*, xx, 276 (Ref.), May, 1887. G. F. B.

3. *On the experimental demonstration of Avogadro's Hypothesis.*—SCHALL has constructed a balance so that the ratio of the density of any given gas to that of hydrogen—and hence the molecular weight of this gas—may be read directly from the deflection. Two glass globes are provided, the capacities of which are as nearly equal as possible, and whose weights are equalized by means of a suitable counterpoise. The balance carries a combined

scale, consisting of an upper fixed part graduated according to the tangent of the deflection-angles, and of a lower part placed behind the former and movable vertically. If one of the two equilibrated globes be exhausted, or if, what is the same thing, the weight of air which it contains be calculated from its capacity and this weight be added to the globe full of air, a deflection-angle will be obtained whose tangent is proportional to this excess of weight. If now the same globe be filled with a given gas, a second deflection-angle will be obtained whose tangent will be proportional to the algebraic sum of the weight of the air and the excess of weight of the gas. Hence, the tangent of the sum of the two deflection-angles is proportional to the weight of the gas. It is necessary, therefore, only to divide this tangent into as many parts as there are units in the molecular weight of the gas employed. The movable scale can therefore be empirically adjusted either with a pure gas or by means of the corresponding weight. Since, however, the sum of the deflection-angles is a function of the temperature and pressure, it is necessary of course to adjust the movable part of the scale for the given conditions. —*Ber. Berl. Chem. Ges.*, xx, 1433, May, 1887. G. F. B.

4. *On the Evolution of Sulphurous oxide and of Oxygen in Kipp's Apparatus.*—NEUMANN has extended the use of Kipp's apparatus for the ready evolution of gases, first suggested by Winkler for chlorine. For sulphurous oxide, he proposes a mixture of three parts calcium sulphite and one of gypsum made into cubes, as in Winkler's method. These cubes are placed in the middle bulb of an ordinary Kipp's apparatus and crude concentrated sulphuric acid is made to act on them. Half a kilogram of cubes yielded the author a constant current of gas for thirty hours. They remained unaltered in shape, no gypsum falling to the bottom of the vessel. It is desirable to moisten no more of the cubes than is necessary to produce the amount of gas required. The evolution of oxygen in this way is effected by the use of cubes made of a mixture of two parts barium peroxide, one part manganese peroxide and one part gypsum. The evolution of the oxygen is produced by means of hydrogen chloride solution of a specific gravity of 1·12 diluted with an equal quantity of water. In the reaction there is evolved beside the oxygen a little chlorine; and hence it is necessary to wash the gas in an alkali solution, as is the case with the oxygen which is evolved by heating potassium chlorate.—*Ber. Berl. Chem. Ges.*, xx, 1584, June, 1887. G. F. B.

5. *On the Vapor-density of Tellurium tetrachloride and on the Valence of Tellurium.*—Of the elements of the sulphur group, no compounds are known, permanent in the state of vapor, in which for each atom of the element there are more than two of a univalent radical. The compounds SCl_4, $SeCl_4$ and $TeCl_4$ are known, it is true, but the first is permanent even in the liquid state, only at $-21°$, and the second decomposes at 218°, yielding a vapor desity of 3·922 instead of 7·63; being broken up into selenium

dichloride and free chlorine. Michaelis has undertaken a study of tellurium tetrachloride, the vapor density of which has not thus far been determined. On preparing this substance the author found that it was much more volatile than the books stated, and that it boiled constantly at 380°. For its production a flask was employed somewhat similar to that which is used for distilling liquids in indifferent gases, but in which the lateral exit tube for the vapor was widened to avoid obstruction by the solid chloride formed. This lateral tube passed into the vertical tube of a second similar flask, the chloride distilling directly from one of these flasks to the other. On admitting the chlorine and gently heating, the tellurium passes first into the dichloride, which is dark brown when fused and gives a dark red vapor, and then with considerable increase of volume into the tetrachloride. This when fused is amber yellow and gives a vapor of the same color, but solidifies into a colorless, crystalline and very deliquescent mass. By a second distillation in a current of chlorine, it was entirely freed from the dichloride. Redistilled in carbon dioxide gas, it boiled constantly at 380°, and its analysis agreed closely with the formula $TeCl_4$. The vapor density was determined by Victor Meyer's method, the apparatus being filled with dry nitrogen, and great care being taken to avoid the presence of moisture. In sulphur vapor at the temperature of 448°, two determinations gave the values 9·028 and 9·224; the calculated value from the formula being 9·32. In the vapor of phosphorus pentasulphide at 530°—and therefore 150° above the boiling point of the tetrachloride—the values 8·859 and 8·468 were obtained. Hence it appears that tellurium tetrachloride does not suffer decomposition even at this temperature, thus resembling the analogous chlorides of tin, of silicon and of titanium; and moreover that its formula in the state of vapor is actually $TeCl_4$. The author regards it as proved, therefore, that tellurium has certainly a valence as high as four; and from its analogies with sulphur and selenium that this fact is probably also true of these elements.—*Ber. Berl. Chem. Ges.*, xx, 1780, June, 1887. G. F. B.

6. *On Diamide* (*Hydrazine*).—When diazoacetic ether is treated with hot concentrated solution of potassium hydrate, Curtius has observed the formation of a new diazo-fatty acid. The potassium salt is distinguished from previously described diazo-compounds by the fact that the diazo-acid set free from it by the addition of a mineral acid is not decomposed with the evolution of nitrogen, but separates in gold yellow scales. If an aqueous solution of this diazo-acid be digested a short time with very dilute sulphuric acid, it becomes colorless without evolving gas, and the solution on cooling deposits a colorless and magnificently crystalline body. This substance is the sulphate of the long sought diamide (hydrazine) $H_2N . NH_2$. In consequence of its slight solubility in water it is easily obtained pure. On warming its salts with alkali solution, diamide is set free as a permanent gas, possessing a very peculiar odor, scarcely recalling that

of ammonia, but strongly attacking the mucous surfaces when breathed. The gas is very readily soluble in water, blues reddened litmus paper strongly, and when not too dilute produces white fumes with hydrogen chloride. It is exceedingly permanent on heating, but has a powerful reducing action. Fehling's solution and ammoniacal solution of silver are at once reduced, and neutral copper sulphate yields a dense red precipitate with it. Mercuric chloride is reduced by it to mercurous chloride. Its salts evolve gas actively when mixed with nitrites. —*Ber. Berl. Chem. Ges.*, xx, 1634, June, 1887. G. F. B.

7. *Method of observing the action of Magnets on Liquids;* by S. T. MOREHEAD.—Some weeks ago one of my students, Mr. J. C. Child, and myself were working with a diamagnetic instrument, simply repeating well known experiments. Plücker's method of observing the diamagnetism of liquids having failed in our hands to give satisfactory results, we hit upon a method which was new to us and which was very satisfactory. Into a glass tube of about four or five millimeters internal diameter a small quantity of liquid was introduced forming a short cylinder. This tube was placed horizontally at right angles to the line joining the poles of the magnet with the liquid nearly between the poles. When the current was turned on, the liquid was very evidently repelled. Water was repelled through a distance of about half a centimeter; wood spirit through a greater distance. By moving the tube in the direction of its length the wood spirit could be pushed any distance through the tube. The amount of motion is of course a function of the resistances due to adhesion and friction as well as of the repulsive force. The attraction of liquids is easily shown by the same method.

A single modification of the above plan of proceeding is to incline the tube slightly so as to make the liquid flow toward the poles. If the required velocity be not too great the magnet acts as a break to stop the motion. It is well to bend the tube up a little at each end to prevent the liquids from flowing out. This method is well adapted for projection so as to be seen by large audiences.

Washington and Lee University, Lexington, Va., May 9, 1887.

8. *Comparison of the radiations from melting platinum and silver.*—M. J. VIOLLE has studied these radiations by means of a thermopile, one surface of which received the radiations and the other was exposed to a known source of heat in such a manner as to bring the needle of the galvanometer to zero. It was found that the total radiation of melting platinum is fifty-four times that of melting silver.—*Comptes Rendus*, July 18, 1887, p. 163. J. T.

9. *Solidification of liquids by pressure;* M. E. H. AMAGAT has succeeded in solidifying bichloride of carbon (C_2Cl_4) by pressure. The disposition of his apparatus enabled him to photograph the resulting crystalline body. C_2C_4 solidifies under the following conditions.

At	19°·5	under pressure of 210 atmospheres.
"	0·	" " " 620 "
"	10·	" " " 900 "

M. Amagat suggests that there may be for each liquid a temperature above which solidification cannot take place under any pressure: that is to say, a critical point of solidification.—*Comptes Rendus*, July 18, 1887, p. 165. J. T.

10. *The Conductibility for heat of Bismuth in the magnetic field.*—M. A. RIGHI announces that the heat conductibility of bismuth varies in a magnetic field. In other words, that a rotation of the isothermals analogous to the Hall phenomenon takes place. —*Comptes Rendus*, July 18, 1887, p. 168. J. T.

11. *Size of the Silver Molecule.*—In an exhaustive paper upon methods of measuring thin films, OTTO WIENER makes certain measures of the thickness of a film of silver which can just be perceived by the eye, and arrives at the conclusion that 0·2 millionths of a millimeter is an upper limit of the diameter of a silver molecule.—*Annalen der Physik und Chemie*, No. 8^a, 1887, pp. 629–672. J. T.

12. *Changes in the Ohm.*—HIMSTEDT has repeatedly re-measured certain standards constructed of german silver and has discovered that, independent apparently of changes of temperature, the resistance of german silver undergoes a slight change. He calls attention to the custom of Messrs. Siemen and Halske of keeping their german silver wire six months after it is covered and wound before it is used for electrical standards of resistance. The experiments of Himstedt supports this procedure of the manufacturers, although no reason is assigned for it. It is better, therefore, to compare with a mercury standard, although the extent of the change of the german silver standards is too small to affect their use in the arts.—*Ann. der Physik und Chemie*, No. 8^a, 1887, p. 617. J. T.

13. *The Chemistry of the Sun;* by J. NORMAN LOCKYER. 8°, pp. xix and 457. Macmillan & Co., London, 1887.—The prime object of this volume is to set forth the theory of dissociation which Mr. Lockyer propounded many years ago, together with the various researches which he has himself carried on to test the theory, and also to show what bearing the investigations and observations of other scientists have upon the same. The earlier chapters of the book are preliminary and are devoted to a history of the work done upon the solar spectrum previous to the last twenty years; the rest of the work is a rehearsal of later work, and a comparison of the theory with facts.

Mr. Lockyer's theory is thus stated (p. 260): "chemists regard matter as composed of atoms and molecules. The view now brought forward simply expands the series into a larger number of terms, and suggests that the molecular grouping of a chemical substance may be simplified almost without limit if the temperature be increased." The earlier hypothesis of the structure of the solar atmosphere and that propounded by Mr. Lockyer he thus contrasts (p. 303). On the old hypothesis:

(1.) We have terrestial elements in the sun's atmosphere.

(2.) They thin out in the order of vapor density, all being represented in the lower strata, since the temperature of the solar atmosphere at the lower levels is incompetent to dissociate them.

(3.) In the lower strata we have especially those of higher atomic weight, all together forming a so-called "reversing layer" by which chiefly the Fraunhofer spectrum is produced.

The new hypothesis changes these to:

(1.) If the terrestrial elements exist at all in the sun's atmosphere they are in process of ultimate formation in the cooler parts of it.

(2.) The sun's atmosphere is not composed of strata which thin out, all substances being represented, at the bottom; but of true strata, like the skins of an onion, each different in composition from the one either above or below.

(3.) In the lower strata we have not elementary substances of high atomic weight, but those constituents of the elementary bodies which can resist the greater heat of these regions.

Mr. Lockyer discusses at length the variations of spectral lines which are usually regarded as belonging to iron, calcium and other chemical elements, as they appear in the solar spectrum, the solar prominences, the electric spark, the electric arc and the Bunsen flame. In this comparison of spectra of matter presumably at different temperatures he finds support for his new theory. Also from seven series of solar spots each series containing 100 spots, observed mainly by his assistants Messrs. Lawrance and Greening, between 1879 and 1885 he obtains like arguments. Additional arguments are obtained from a detailed discussion of the prominence lines, and from the spectra of the corona seen during eclipses. H. A. N.

14. *Joint Scientific Papers of James Prescott Joule.* Published by the Physical Society of London. 391 pp. 8vo. London, 1887. (Taylor and Francis).—The first volume of the papers by Dr. Joule, republished by the London Physical Society, was noticed in volume xxviii of this Journal. The present volume will be also welcome to physicists. It includes a short paper on experiments and observations on the mechanical powers of electro-magnetism, steam and horses, by Dr. Joule and Dr. Scoresby; a series of papers on atomic volume and specific gravity, and another series on the relation in volumes between simple bodies, their oxides and sulphurets, etc., by Dr. Joule and Sir Lyon Playfair; finally a series of papers by Dr. Joule and Sir Wm. Thomson, on the thermal effects of fluids in motion.

II. Geology and Mineralogy.

1. *Note on the Characters and Mode of Formation of the Coral Reefs of the Solomon Islands, being the results of Observations made in* 1882–84; by H. B. Guppy, M.B., F.G.S., during the surveying cruise of H. M. S. "Lark."—Mr. Guppy describes the coral reefs of the Solomon Islands with fulness and much val-

uable detail. After presenting the facts as to various reefs, and the depths of the living corals, the limit of which he finds to be beyond thirty fathoms, he presents his conclusion with regard to the origin of the barrier reefs. He observes that, after coral reefs have begun about an island, the detritus, made from the corals, will collect in a band on the outer slope of the reef, at depths near the limit usually attributed to growing coral, and extend, as may be determined, by the presence, position and slope of the declivities. In such a zone of detritus the corals do not thrive. But below it the slopes may be gentle again, and there may be another zone of corals; and when so, the corals of this outer zone may rise and make a surface reef, separate from the first or fringing reef by a region of detritus; the outer reef so made will be a barrier reef. An elevation in the region may bring other parts of the sea-bottom about islands within coral reef depths, and thus the process may be repeated and extended. The objection to the theory that the depths inside of barrier reefs are sometimes forty to sixty fathoms is met on the ground of the possibility that the lower coral reef limit may be as great as this, and on his own observation that "off the reef of Choiseul Bay I did not seem to have reached the lower limit in soundings of forty fathoms." Mr. Guppy states that his views are substantially the same with those of Prof. Joseph Le Conte, as presented in his paper on the Florida barrier reefs (this Journal, II, xxiii, 46). Mr. Guppy gives other conclusion from his observations.

What is needed to place the subject entirely above the level of hypothesis is a series of generous borings in several atolls and barrier reefs, as the writer has elsewhere suggested. It is not a question, merely, as to how reefs have been made, but whether or not great downward as well as upward change of level is possible in Quaternary or recent times within the oceanic limits, and it therefore calls for whatever expenditure may be necessary to carry on such borings effectually. J. D. D.

2. *Explorations in Florida;* by ANGELO HEILPRIN, 134 pp., large 8vo, with 20 plates. Philadelphia. *Transactions of the Wagner Free Institute of Science of Philadelphia.* Published under the direction of the Faculty, May, 1887.—The Wagner Free Institute of Science in Philadelphia, was founded by the late WILLIAM WAGNER, of that city, and sustained as an Institute of free lectures by his annual gifts for thirty years; and at his death, in January, 1885, all his property was bequeathed to it. The faculty consists of four professors with Dr. Leidy as the president. The trustees have appropriated part of the fund to aid in original research, and the memoir of Mr. Heilprin is the first of the reports thus obtained.

The expedition to Florida was organized early in 1886, with the generous coöperation of the Academy of Natural Sciences and Messrs. Joseph Willcox and C. H. Brock, who joined it, Mr. Heilprin being put in scientific charge. The schooner Rambler was chartered for the excursion.

Mr. Heilprin's report describes the features of the region visited, its geology, and its paleontology, besides making some contributions to its zoology. Seventeen of the twenty plates are covered with admirable autoglyphic figures of the fossils; and besides these, the snake *Tropidonotus taxispilotus* is figured on plate 17; the fish *Ictalurus Okeechobeënsis* on plate 18, and the new species of Aplysia, *A. Willcoxi,* on plate 19.

A history of former geological investigations in Florida is given which includes a notice of Conrad's identification of the Vicksburg Tertiary at Tampa Bay; an account of the work of Dr. E. A. Smith, geologist of Alabama, who found a considerable part of the northern half of Florida to be underlaid by a fossiliferous limestone, whose fossils were studied by Mr. Heilprin and referred to the Oligocene, and found to include, besides great numbers of *Orbitoides complanata,* the first then recognized of American Nummulites, named *N. Willcoxi;* and Dr. J. C. Neil's discovery of Mammalian remains, near Archer, in Alachua county, Florida, among which Dr. Leidy recognized species of Mastodon, Rhinoceros, Tapir, Horse, Llama, Camel and Hog. The results of the explorations made are then given, with the following general conclusions.

The surface rocks of Florida are exclusively Tertiary and Quaternary. No observed facts sustain the coral theory of formation propounded by Agassiz; on the contrary, they prove that the coral tract of Florida is confined to a border region on the south and southeast; that the few fossil corals found in Tertiary deposits are sporadic growths, not parts of reef formations. The formations represented are the Oligocene, Miocene, Pliocene and Post-pliocene, which, commencing with the oldest at the north, follow one another in regular succession from north to south, thus clearly indicating the course of progress in the growth of the Peninsula. The successive belts are not directly east and west in course, but to the eastward are deflected northeastward so as to conform approximately to the Atlantic border. No Eocene rocks were found, but such may exist in the northern section of the State, and possibly they may comprise part of what is called Oligocene. The different formations are horizontal or very nearly so; and they follow one another without any broad or distinct lines of faunal separation. The northern half of Florida appears to be covered with a deep-sea formation, and the southern with beds made in a comparatively shallow sea. The elevation of the area, especially the southern part, went on very gradually, without leaving any marks of disturbance. Before the elevation was completed, a large part, especially the southern, was a submerged flat or plain, the shallow coverings which were favorably situated for a profusion of animal life, and "the accumulation of reef structures and of vast oyster and scallop banks;" and freshwater streams existed as is proved by the commingling of marine and fluviatile mollusks in the deposits of the Caloosahatchie. The derivation of the modern species of the coast from older Florida species is easily traced out.

Portions of a skeleton of man, including an entire head, were formerly obtained near Sarasota Bay, at a locality known as Mrs. Hanson's, from a partially indurated sandstone, and fragments including a vertebra were found by Mr. Heilprin. No fossils were found in the deposit to indicate its precise age.

3. *The summit-plates in Blastoids, Crinoids and Cystids and their Morphological relations;* by CHARLES WACHSMUTH and FRANK SPRINGER. Proc. Acad. Nat. Sci. Phil., March 29th, 1887. pp. 33 and one plate.—This paper is chiefly devoted to a criticism of certain views expressed by Etheridge and Carpenter in their recently published catalogue of the Blastoidea in the Geological Department of the British Museum, with regard to the morphological relations of the summit-plates in the three groups mentioned in the above title. Etheridge and Carpenter argue that the six proximal plates surrounding a central one in the summit of typical Blastoids and Palæocrinoids are the homologues of the five oral plates in Neocrinoidea, and that in both cases they may be traced by a series of parallel transitions from a simple form of summit consisting of only five plates. Wachsmuth and Springer undertake to prove by a critical analysis of the forms relied upon by Etheridge and Carpenter, based on material in an excellent state of preservation, that their assumed simple form does not exist at all in the Blastoids. Further, that the Palæocrinoids, such for example as Haplocrinus and Allagecrinus, bearing the simple form of five plates on the ventral side, do not present analogous cases. Their theory, Wachsmuth and Springer contend, wholly fails to show any valid homology for the central summit plate inside the proximal ring in Palæocrinoids, (which covers the actinal center, just as the orals do in Neocrinoids) but requires the assumption of an "orocentral" plate; thus introducing an element in Echinoderm morphology which is altogether unrepresented in other echinoderms. They claim that before the homology proposed by Etheridge and Carpenter can be accepted they must show by what developmental process the five oral plates are transformed into six proximals, especially in cases where they are not modified by anal structures. Also that they must demonstrate the existence of their hypothetical "orocentral." The plate of illustrations consists of diagramatic figures of the forms of summit mentioned in the discussion. C. A. WHITE.

4. *Cliftonite, a cubic form of graphitic carbon.*—The meteoric iron found in the district of Youndegin, West Australia, in 1884, has afforded an interesting form of carbon resembling graphite but in cubic form; this is described by FLETCHER in a recent number of the *Mineralogical Magazine.* Four fragments of the iron were found, the largest weighing $25\frac{3}{4}$ pounds; in addition there were a number of pieces aggregating 17 pounds, consisting essentially of the magnetic oxide of iron, doubtless due to the weathering of the original mass. The iron has a specific gravity of 7.85. It is very hard and contains numerous enclosures of

schreibersite; it does not yield distinct figures when etched. An analysis afforded:

Fe	Ni	Co	Cu	Mg	P	S	Insol. cubes.	
92·67	6·46	0·55	tr.	0·42	0·24	none	0·04	= 100·38

The cubic crystals, obtained from dissolving a piece of the iron, were about a hundred in number, the average thickness of the larger ones being one-hundreth of an inch. The cubic faces predominate, but the edges in some cases are replaced by dodecahedral planes. The hardness is 2·5, the specific gravity 2·12, the color black. A series of chemical tests led to the conclusion that the material was carbon, resembling graphite in most of its characters but considerably harder and unlike in form. The author recalls a paper by Haidinger, published in 1846 on "Graphite pseudomorphous after iron pyrites" obtained from a graphite nodule in the Arva meteoric iron, and concludes that their nature must have been the same as those from the Youndegin iron. The pyrite hypothesis, however, is shown to be untenable as well on crystallographic grounds, as because pyrite is thus far an unknown mineral in meteorites. In some respects the Youndegin crystals suggest pseudomorphs, more especially since they sometimes consist simply of a hollow shell, but in other regards they appear to be original forms. The author is inclined to hold them to be an allotropic form of carbon distinct from diamond and graphite, and he names it Cliftonite after Mr. R. B. Clifton, Professor of Physics at Oxford.

III. Miscellaneous Scientific Intelligence.

1. *The Height of Summer Clouds.*—A knowledge of the heights and movements of the clouds is of much interest to science, and of especial importance in the prediction of weather; the subject has therefore recieved much attention during recent years from meteorologists, chiefly in this country and in Sweden. In the last published Report of the Meteorological Council for 1885–86 will be found an account of the steps taken by that body to obtain cloud-photographs; and in the *Meteorologische Zeitschrift* for March last, Ekholm and Hagström have published an interesting summary of the results of observations made at Upsala during the summers of 1884–85. They determined the parallax of the clouds by angular measurements made from two stations at the extremities of a base of convenient length, and having telephonic connection. The instruments used were altazimuths, constructed under the direction of Prof. Mohn, specially for measuring the parallax of aurora borealis. A full description of these instruments and of the calculations will be found in the *Acta Reg. Soc. Sc. Ups.* 1884. The results now in question are based upon nearly 1500 measurements of *heights;* the *motions* will form the subject of a future paper. It was found that clouds are formed at all levels but that they occur most frequently at certain elevations or stages. The following are,

approximately, the mean heights, in feet, of the principal forms: —Stratus, 2000; nimbus, 5000; cumulus (base), 4500, (summit) 6000; cumulo-stratus (base), 4600; "false-cirrus" (a form which often accompanies the cumulo-stratus), 12,800; cirro-cumulus, 21,000; cirrus, 29,000 (the highest being 41,000). The maximum of cloud-frequency was found to be at levels of 2300 and 5500 feet. Generally speaking, all the forms of cloud have a tendency to rise during the course of the day; the change, excepting for the cumulus-form, amounting to nearly 6500 feet. In the morning, when the cirrus clouds are at their lowest level, the frequency of their lowest forms—the cirro-cumulus—is greatest; and in the evening, when the height of the cirrus is greatest, the frequency of its highest forms—the cirro-stratus—is also greatest. With regard to the connection between the character of the weather and the height of the clouds, the heights of the bases of the cumulus are nearly constant in all conditions. The summits, however, are lowest in the vicinity of a barometric maximum; they increase in the region of a depression and attain their greatest height in thunderstorms, the thickness of the cumulo-stratus stretching sometimes for several miles. The highest forms of clouds appear to float at their lowest levels in the region of a depression. The forms of clouds are identical in all parts of the world, as has been shown in papers lately read by the Hon. R. Abercromby before the English and Scottish Meteorological Societies.—*Nature* xxxvi, 206.

2. *American Association for the Advancement of Science.*— The thirty-sixth meeting of the Association was held in New York City during the week from August 10th to August 16th, in the buildings of Columbia College. The meeting opened with an address of welcome from Rev. F. A. P. Barnard, President of the institution which had offered hospitality to the members of the Association, to which the President, Professor S. P. Langley, replied. The opening addresses before the Sections by their Vice-Presidents were as follows: Section B, W. A. Anthony, on the importance to the advancement of physical science of the teaching of physics in the public schools; Section C, A. B. Prescott, on the chemistry of nitrogen as disclosed in the constitution of the Alkaloids; Section D, E. B. Coxe; Section E, G. K. Gilbert, on the work of the International Congress of Geologists; Section F, W. G. Farlow, on vegetable parasites and evolution; Section H, D. G. Brinton, on a review of the data for the study of the prehistoric chronology of America; Section I, H. E. Alvord, on economy in the management of the soil.

In the evening of the opening day the retiring President, Professor Edward S. Morse delivered an able address upon Evolution. A lecture by Professor Henry Drummond of Glasgow, on the Heart of Africa, giving observations on a recent scientific tour to the region of the Zambesi and Lake Tanganyika, was listened to by a large and interested audience on Monday evening.

The list of papers accepted is given below; some of them were

followed by a prolonged and interesting discussion, as for example those devoted to the food question before Section I. The Geologists gave up the working part of Friday to a consideration of the Report of the American Committee of the International Congress of Geologists. The whole ground was gone over with care and it may be hoped that the discussion will lead to good results; the same topic had formed the subject of Mr. Gilbert's address before Section E, as noted above.

The following committees were appointed at the last day of the meeting: E. D. Cope, J. R. Eastman and G. K. Gilbert, a committee to devise methods of obtaining from Congress a reduction of the tariff on scientific books; Miss A. C. Fletcher and Mrs. T. Stephenson, a committee to petition Congress to take the necessary steps to preserve the archæological monuments on the public lands of the United States. A resolution was passed recommending the publication by the Government of an index to the literature of meteorology, now being prepared by Prof. Cleveland Abbe. Another resolution urged President Cleveland to appoint at once a permanent Superintendent of the United States Coast and Geodetic Survey. A third petitioned Congress to provide a Bureau of Standards, by which accurate standards of measure should be established for electricity, heat and light, and arrangements made for the issue of authenticated copies of the same.

The entertainment of visitors was under the charge of several local committees, to whose activity the success of the meeting was largely due. There was a general reception to the Association by the Ladies' Committee in the Metropolitan Opera House on Thursday evening; another reception was given by the Academy of Sciences and several others of less general nature. There were a number of excursions: around New York harbor, to Long Branch by boat, to West Point, and others which need not be particularized.

The next meeting of the Association was appointed for the fourth Wednesday of August, 1888, at Cleveland, Ohio. The President elected for this meeting is Major J. W. Powell; and the Vice-Presidents by sections—Mathematics and Astronomy, Ormond Stone; Physics, A. A. Michelson; Chemistry, C. E. Monroe; Mechanical Science, C. M. Woodward; Geology and Geography, G. H. Cook; Biology, C. V. Riley; Anthropology, Charles C. Abbott; Economic Science and Statistics, C. W. Smiley.

List of Papers accepted for Reading.

SECTION A.—*Mathematics and Astronomy.*

F. N. WILLSON: A completed nomenclature for the principal roulettes.

J. E. KERSHNER: Coefficients of collimation and flexure of transit instruments with broken tubes.

J. R. EASTMAN: The effect of some peculiarities of personal equation.

HENRY FARQUHAR: Variation of personal equation; a criticism.

HENRY B. FINE: The geometric meaning of singular solutions of differential equations of the second and higher orders.

WILLIAM HARKNESS: The visibility of objects as conditioned by their magnitude and brightness, with application to the theory of telescopes.

J. M. SCHAEBERLE: The horizontal flexure of a meridian circle.

ALEX. MACFARLANE: The logical theorems required in elementary geometry. The logical form of geometrical theorems.

J. A. BRASHEAR: A new form of comet seeker. Method of preventing breakage in the polarizing helioscope. Standard dimensions in astronomical and physical instruments.

F. H. BIGELOW: The phenomena of solar vortices.

LEWIS BOSS: A list of stars with large proper motions.

HENRY M. PARKHURST: Photometric observation of asteroids.

J. BURKITT WEBB: Moment of inertia.

R. S. WOODWARD: Method of computing the secular contraction of the earth.

ORMOND STONE: The orbit of Hyperion.

T. C. MENDENHALL: The eccentricities of guessing.

SECTION B.—*Physics.*

L. E. BLAKE: A method of telephonic communication between ships at sea.

J. J. SKINNER: A method of comparing galvanometer coils.

A. A. MICHELSON and E. W. MORLEY: A method for making the wave length of sodium light the actual and practical standard of length. The relative velocity of the earth and the luminiferous ether.

WM. A. ROGERS: Determination of the invariability of the coefficients of expansion of Bailey's metal, of Jessup's steel, and of Chance & Sons' glass, between the limits of $-3°$ and $+97°$ F. Description of a combined chronograph and weight motor. A method of obtaining the constant of gravity from the comparison of musical notes. Time of exposure and mass considered as functions of the rate of saturation of heat in the case of mercury and water. The definition of the Ohm by the equation $R=K\frac{C}{S}$. Determination of the coefficient of expansion of the glass plates used for stellar photography at Cordoba in the years 1872–1875 and 1879–1883. A study of thirty-two mercurial thermometers under variations of temperature between $-25°$ F. and $+95°$ F.

E. E. RIES: The electric current as a means of increasing the tractive adhesion of railway motors and other rolling contacts.

A. MACFARLANE: Notation for physical units.

C. LEO MEES: Experimental determinations of minimum wind-velocity in Washington, O., tornado.

H. S. CARHART: The simultaneous measurement of the speed of an engine and dynamo by electric means.

T. C. MENDENHALL and A. L. MCRAE: The electrical condition of the atmosphere in fair weather and during thunderstorms.

D. B. BRACE: A method of examining magnetic double circular refraction. The transparency of the ether and its possible viscosity.

W. M. DAVIS: A classification of the winds.

W. F. MAGIE: Measurement of surface tension of liquids.

WM. THOMSON: Color blindness of railway employees.

DEVOLSON WOOD: Gravitation ether. Second law of thermodynamics.

C. E. MONROE: Certain phenomena produced by the explosion of gun cotton on metallic plates.

A. B. JOHNSON: The difficulty of determining the direction of the source of sound of fog signals at sea.

J. BURKITT WEBB: A new dynamometer (with working model). Experimental determination of the reaction of a liquid jet. Experiments on the viscosity of oil. A new viscosimeter.

E. L. NICHOLS and W. S. FRANKLIN: The electromotive force of magnetization.

H. E. ALVORD: Influence of topography upon rainfall; from observations on Houghton Farm during 1884.

M. A. VEDER: Is terrestrial magnetism concerned in atmospheric movements?

T. A. EDISON: The pyromagnetic dynamo: a machine for producing electricity directly from fuel. A magnetic bridge or balance for measuring magnetic conductivity.

P. H. Van der Weyde: A peculiar form of undulatory current suited to telegraphing on telephone circuits. Some notes on standard cells.

C. F. De Landero: A relation between the quantities of heat combination in aqueous solution.

E. B. Elliott: The mutual action of the elements of an electric current.

Cleveland Abbe: The Signal Service bibliography of meteorology.

Section C.—*Chemistry.*

Frederick B. Power and Henry Weimar: The constituents of wild cherry bark.

L. M. Norton: The fatty acids of the drying oils.

H. W. Wiley: The chemical composition of the juices of sorghum cane, in relation to the production of sugar.

William P. Mason: Percentage of ash in human bones of different ages. Standardizing hydrometers.

T. H. Norton: The occurrence in nature of a copper antimonide. A new apparatus for fractional distillation. Certain alloys of calcium and zinc. The salts of benzene-sulphonic acid with the amines. Some new metallic salts of benzene-sulphonic acid. The amine salts of para-toluene-sulphonic acid. The action of silicon flouride on acetone. The limits of the direct bromination of acetone and on the action between ammonium sulphocyanide and monobrom-acetone. The action of chlorine on acenaphthene. The urates of ammonium and the amines of the fatty acids. Some new nitroprussides.

Edward W. Morley: Amount of moisture left in a gas after drying with phosphorus pentoxide.

W. H. Herrick: Improvement in stand for electrolysis. Indirect determination of calcium.

Arthur L. Green: A process for the separation of alkaloidal poisons, for students' use.

W. O. Atwater: The determination of nitrogen by soda-lime. Chemical changes accompanying osmose in living organisms as illustrated by the oyster.

Albert N. Leeds: Causes, progress and cure of the recent outburst of typhoid fever at Mt. Holly, N. J. The scientific basis of the feeding of infants.

F. G. Novy: Analysis of two manganese mineral waters. Some higher homologues of cocaine.

H. W. Weld: Composition of Lockport sandstone.

Wm. McMurtrie: Notes on the chemistry of germination. Note on absorption of nitrogenous nutriment by the roots of plants.

Spencer B. Newberry: The significance of "bonds" in structural formulas.

Albert B. Prescott: Positive and negative units of valence.

E. W. Hilgard: The processes of soil formation from the northwestern basalts.

C. F. Mabery: A new method for the preparation of anhydrous aluminium chloride. The action of aromatic amines upon certain substituted unsaturated acids. Constitution of the sulphur compounds in crude petroleum oils.

Helen C. DeS. Abbott: A compound rich in carbon occurring in some plants.

E. H. S. Bailey and E. L. Nichols: The delicacy of the sense of taste.

Section D.—*Mechanical Science and Engineering.*

R. H. Thurston: Nicaraguan woods. Friction of engines.

Albert R. Leeds: The American system of water purification.

H. T. Eddy: A new method of finding an equivalent uniform load, producing bending moments approximately equal to the maximum moments under a moving train. The deflection of girders and trusses. Reaction polygons and their properties.

Charles E. Monroe: An improved method for testing metals.

DeVolson Wood: Effect upon the strength of iron of subjecting it to a pull while hot. Rankine's solution of the problem of turbines. Downward draft device for a furnace.

J. Burkitt Webb: A new high speed steam engine indicator.

D. S. Jacobus: Errors of approximate calculations of the effect of the inertia of the moving parts of a steam engine.

J. E. DENTON: The theoretical effect of errors of observation in calorimeter experiments for determining the latent heat of steam. Improved arrangement of Siemen's platinum electrical pyrometer.

T. C. MENDENHALL and JOHN MACK: The uniformity of planimeter measurements.

FRANK C. WAGNER: An analysis of dynamo design.

P. H. DUDLEY: Mechanical inspection of railway tracks and results obtained.

MANSFIELD MERRIMAN: The theories of the lateral pressure of sand against retaining walls.

H. C. TAYLOR: The question of Isthmian transit.

R. E. PEAVY: The Engineering features of the Nicaragua Canal route

J. F. BRANSFORD: Climatic and sanitary notes on the Nicaragua Canal route.

J. W. MILLER: Historical and geographical notes concerning the Nicaragua Canal route.

J. R. HASKELL: National armament.

SECTION E.—*Geology and Geography.*

H. S. WILLIAMS: The different types of Devonian in North America.

EDWARD ORTON: The Trenton Limestone as a source of petroleum and inflammable gas in Ohio and Indiana.

CHAS. S. PROSSER: Section of well at Morrisville, N. Y. The Upper Hamilton group of Chenango and Otsego counties, N. Y.

ALEXIS A. JULIEN: A geological section at Great Barrington, Mass.

N. H. WINCHELL: The granite and quartzite contact at the Aurora mine, Gogebic iron range, Ironwood, Michigan. The "slate conglomerate" of the original Huronian the parallel of the Ogishke sandstone of Minnesota. The Animike black slate and quartzite and the Ogishke conglomerate of Minnesota, the equivalent of the original Huronian. An unconformable conglomerate lying on the Marquette iron-ore rocks at Negaune and Ishpeming, Michigan. The "Huronian System."

J. EDGAR: The Potsdam Sandstone in Southern Pennsylvania.

E. W. CLAYPOLE: The four great sandstones of Pennsylvania. "Lake Cuyahoga," a study in glacial geology.

J. F. KEMP: Notes on the eruptive rocks of the Archæan in the New York and New Jersey Highlands.

JOSEPH F. JAMES: Geological section of Southwestern Ohio.

H. P. CUSHING: Notes on the Berea grit in Eastern Ohio.

JOSEPH E. WILLET: The southern drift.

THEO. B. COMSTOCK: Notes on the extinct thermal springs of Arkansas. The unknown geology of Illinois.

ROBERT T. HILL: Notes on the Texas section of the American Cretaceous.

W. B. SCOTT: The Upper Eocene lacustrine formations of the United States.

J. W. SPENCER: Sand-bowlders in the drift, or subaqueous origin of the drift in central Missouri. Notes on the theory of glacial motion. Glacial erosion in Norway, with some notes on northern ice action.

W. J. MCGEE: The Columbia formation.

JOHN C. BRANNER: The origin of the terraces along the Ohio river between Cincinnati and Louisville. Southern limit of the drift in Kentucky and Indiana.

C. H. HITCHCOCK: Genesis of the Hawaiian islands.

H. C. HOVEY: A description of two caverns near Manitou, Colorado.

FRED. P. DEWEY: Photographs of the interior of a coal mine.

JOS. F. JAMES and U. P. JAMES: The monticuliporoid corals of the Cincinnati group, with a critical revision of the species.

CHAS. D. WALCOTT: Discovery of fossils in the lower Taconic of Emmons. Section of the lower Silurian (Ordovician) and Cambrian strata in central New York, as shown by a deep well near Utica.

L. C. JOHNSON: Notes on the geology of Florida.

J. S. NEWBERRY: The plants and fishes of the triassic rocks of New Jersey and the valley of the Connecticut. The fossil fishes of the Cleveland shale. The flora of the Amboy clays.

WILLIAM M. FONTAINE: The flora of the Potomac formation in Virginia.

D. S. MARTIN: The geology of New York City and environs.

N. L. BRITTON: Recent field work in the Archæan of Northern New Jersey and Southeastern New York.

J. H. MERRILL: The age of the limestones of Westchester County, N. Y.

F. D. CHESTER: The state line serpentines and associated rocks: a preliminary notice of the serpentines of southeastern Pennsylvania.

G. H. WILLIAMS: Exhibition of a new petrographical microscope of American manufacture. Some examples of the dynamic metamorphism of the ancient eruptive rocks of the south shore of Lake Superior.

J. S. DILLER and G. F. KUNZ: Is there a diamond field in Kentucky?

G. F. KUNZ: The diamond found at Dysartville, N. C. Rock crystal from Ashe County, N. C. The agatized and jasperized wood from Chalcedony park, Arizona.

R. OGDEN DOREMUS: On the successful protection of the Egyptian Obelisk in Central park, against the ravages of two winters, by saturating its surface with melted paraffine wax.

RICHARD OWEN: The relation of the pole of the land hemisphere to continents, to the magnetic system and to seismic force. Relation between geographical forms and geological formations.

SECTION F.—*Biology.*

N. L. BRITTON: Notes on the Flora of the Kittatinney Mountains.

H. H. RUSBY: The cultivated Cinchonas of Bolivia.

JOHN M. COULTER: Developments of the Umbellifer fruit.

ROBERT P. BIGELOW: On the structure of the frond in Champia parvula Harv.

W. G. FARLOW: Apical growth in Fucus. Æcidium on Juniperus Viginiana.

W. J. BEAL and C. E. ST. JOHN: Study of the hairs in Silphium perfoliatum, and Depsacus lacinatus in relation to insects.

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Professor SPENCER F. BAIRD, of Washington, died at Wood's Holl, Mass., on Aug. 19. A notice of his life and work is deferred until another number.

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[THIRD SERIES.]

ART. XXVII.—*The relation between Wind Velocity and Pressure;* by H. ALLEN HAZEN.

FOR more than a century physicists have attempted a solution of the problem with regard to the relation between wind-velocity and pressure; yet the experiments tried by different observers and under varying conditions have often been contradictory and difficult to reconcile. Two methods of investigation have been very frequently adopted, the one by carrying a plate either in a straight line or in a circle, and the other by allowing a current of air to impinge normally upon the plate. The pressure has been measured by using delicate appliances on the plate; but it will be readily seen that there must be great uncertainty in such measurements, if made at the extremity of a long arm, and, moreover, the use of any attachment whatever to the plate would tend to dampen the effect we wish to measure, i. e. the plate would be restrained from following the actual movements imposed upon it by the accumulation or flowing off of the air from its front.

Borda's experiments.—Perhaps the most reliable of the earlier results are those by Borda in 1763. He used a kind of fly-wheel, with vertical axis and a horizontal arm a little over 7 feet in length. On the end of this arm he placed the flat plate,

or any other object, the resistance of the air against which he wished to learn, and observed the uniform velocities of the fly-wheel under the action of different weights. He used plates 9·59, 6·39 and 4·26 in. on the edge, and weights of 8·8, 4·4, 2·2, 1·1 and ·55 pounds, in generating velocities. The observations may be very satisfactorily united into the following formula:

$$p=(\cdot 0031+\cdot 00035c)\ SV^2$$

In which $p=$ pressure in pounds; C= contour of plate in ft.; S= surface in sq. ft.; V= velocity in miles per hour. This notation will be preserved throughout this paper. The formula may be converted into velocity in ft. per second by multiplying by $(22\cdot 15)^2$.

Hagen's experiments.—By far the most careful experiments with a whirling machine were those of Hagen in 1873. The arm in this case was 8 ft. in length. The velocity ranged from 1 to about 4 miles per hour. The room seems to have been quite small, as, with the latter velocity, the air was set in feeble rotation. The plates ranged in size from 4 to 40 sq. in. area. He found, as in the case of Borda, that the pressure per sq. ft. increased with the larger plates. His formula is:

$$p=(0029+\cdot 00014c)\ SV^2.$$

These experiments were conducted with so great care, and so complete an elimination of all apparent sources of error, that they alone were depended on by Prof. Ferrel in his recent discussion of this question. See Annual Report Chief Signal Officer, 1885, Part ii, pp. 314 and 407.

Experiments at Metz, France.—MM. Piobert, Didion and Morin, at Metz, used a plate of 10·764 sq. ft. area, allowing it to drop vertically a distance of nearly 47 ft. in a foundry. The times, spaces, and velocity of fall were measured electrically, and the following approximate pressure of the air was obtained:

$$p=(\cdot 002+\cdot 0035)\ SV^2.$$

To test the effect of the size of the plate, another series of results was obtained with the above plate, and another of ¼ its size. The larger plate required a little longer time in falling through any given space than the smaller, hence the pressure per sq. ft. upon it must have been greater than on the smaller. This is in the same direction as the results of Borda and Hagen, but the difference was very slight and the conditions were quite unsatisfactory. The short distance and time of fall preclude any but the most general conclusions.

Experiments in Washington.—In Nov., 1886, it was decided to make a short investigation on this subject. It was necessary to adopt the simplest and cheapest possible apparatus. At-

tempts were made, at first, to use a tricycle in calm weather. Plates were carried on different days and at varying speeds, but it was found, finally, that the resistance to be measured was so small, and the apparatus so sensitive that the jarring, even on the smoothest pavement, and very slight breaths of air, vitiated the results, and rendered the method unsatisfactory. The same may be said of experiments on a whirling machine, in the open air, used in connection with the pastime "hobby horses." In this case the arm of the apparatus, 12 ft. in length, was increased to 17 ft. by the use of gaspipe. The pressures were measured by the elongation of a spiral spring. The plate, suspended by delicate threads from an upright, was kept vertical by pulling on the spring and its observed elongation indicated the pressure exerted. In both these cases the greatest velocity attained was 12 miles per hour. In the latter case the experiments were interfered with by the effects of centrifugal action upon both the plate and the observer. The results may be expressed by the formula:

$$p = \cdot 005\ SV^2.$$

The plates ranged from 144 to 576 sq. in. area.

Experiments were next tried in a room 14 by 25 feet, and afterward, with the same apparatus enlarged, at the building of the U. S. Fish Commission, in a room about 50 ft. sq., but giving only 40 ft. clear space. The details of the latter apparatus will be given here. A heavy gas pipe, 34 feet in length, was suspended by two ropes from a beam in the attic, a hole having been cut in the ceiling of the operating room. The point of suspension was just below the swivel of a chain, and the ropes could be spread to any desired angle on the bar. The motive power was obtained by winding up the ropes one upon the other, by turning the lower part of the swivel, and the unwinding produced a most excellent, uniform, and steady motion. At the higher rates of speed it was found that the ropes were in danger of cutting each other by the extreme tension. This was obviated by inserting a rod of $\frac{5}{8}$ in. iron, and winding the two ropes upon that. The method of measuring the resistance was to allow the plates, suspended by delicate threads either 4 or 8 feet in length, to swing to various angles. The size of the angle was measured by looking on a scale having such large divisions that they could be read easily at the axis of the apparatus. At first it was proposed that the observer should sit at the centre of the bar and make readings of the scales, as he faced them, at any moment, but it was found that the whole apparatus, notwithstanding its weight of 350 pounds, was so delicate in its adjustments that slight movements of the hand in making a record were felt by the plate. It became necessary,

therefore, to substitute a heavy weight for the observer and make readings of the scale by standing at the centre and gradually turning so as always to face the scales. Four plates were used, two of them at 16 feet, one at 8, and the fourth at 4 feet from the axis of the apparatus. It will be seen that, if the total pressures were proportional to the square of the velocity, that at 16 feet would be just 16 times, and at 8 feet 4 times that at 4 feet. It was also possible, by having two plates at 16 feet, to test the effect of different sizes of plates under absolutely the same conditions, and this was frequently done, a plate of 16 sq. in. area being compared with one of 576 sq. in. If we take the main bar about $\frac{1}{4}$ the length of this just described, and the suspensions of the two plates at 16 feet, we shall have the smaller apparatus first used. The total pressure upon the plate, by theory, was equal to the weight of the plate multiplied by the tangent of the angle of deviation from the vertical. Careful experiment showed that, within the limits of the angle of swing employed, there were no differences due to the slightly diminished quantity of air meeting the plate with the greater angle. The reason for choosing this method of measurement may be of some interest. After coiling a large number of springs of varying degrees of sensitiveness and calibrating them vertically by the use of weights, after the manner of the Joly gravity apparatus, it was decided to test the accuracy of the calibration on the spring used horizontally by measuring the force necessary to draw out a weight suspended by a long cord. It was found that the calibration did not give the correct value for the force, although all the springs gave almost identical results. The force necessary, or the elongation of the spring, when the angle of the weight with the vertical was small, was too slight, and the contrary was true with larger angles, as compared with theory. It was then found necessary to calibrate the springs horizontally by using a pulley, and after that the two curves coincided very satisfactorily. It then appeared that it would be much better to do away with the spring entirely and simply let the plate act like a weight, and then measure the angle of swing. Making the suspending cords of different lengths did not appear to change the result. It was found that the angle of the suspending threads must be quite large, else the plate would take upon itself a wavy motion, twisting back and forth on the line which was its intersection with a vertical plane passing through its center, at right angles to the supporting bar.

One peculiarity in the results was the extreme sensitiveness of the plate; there seemed to be a gradual heaping up of the air in front of the plate as the rotation proceeded, and then a much more rapid falling away causing the plate to drop back. After

several turns the plate became somewhat steadier and showed a slightly less pressure, possibly owing to a slight following after of the air, produced by the motion of the plate. In order to determine the uniformity of the times of revolution, a chronograph was employed, the bar being made to record its own turns. One of these records is here given:

Chronograph Record of Revolutions.

No. of the turn.	Seconds.	No. of the turn.	Seconds.	No. of the turn.	Seconds.
1	4·8	9	3·9	17	3·9
2	4·5	10	3·9	18	4·0
3	4·4	11	3·9	19	3·9
4	4·3	12	3·8	20	4·0
5	4·1	13	3·9	21	4·1
6	4·0	14	3·9	22	4·0
7	3·9	15	3·9	23	3·1
8	3·9	16	3·9	24	4·2

This table shows that after the first 6 turns the motion became uniform and continued so for at least 14 turns. After a long series of observations the following formula was obtained:

$$p = (\cdot0032 + \cdot00034c)\ SV^2.$$

There is a most remarkable and unexpected coincidence between this result and that of Borda, and this correspondence seems to indicate that there could hardly be any constant errors, as the apparatus was so entirely different from Borda's. It will be noted that Hagen's formula was derived after the total pressure had become uniform, and it may be said that nearly the same result would have been found after the first 15 or 20 revolutions of the above apparatus.

The later experiments with an arm of 16 feet developed the fact that there was no increase of pressure per square foot with the larger plates, as in the previous results, but that it was constant for sizes from 16 to 576 square inch area. The formula from these results was:

$$p = \cdot0034\ SV^2, \text{ Rouse's experiments.}$$

All the results thus far, except those at Metz, were derived with whirling machines, and it is of interest to compare them with others made with an air current impinging upon the plate. Such, probably, are those of Rouse in the 18th century. His formula was as follows:

$$p = \cdot0049\ SV^2, \text{ Thibault's results.}$$

In these experiments plates of 1·162 and 1·531 square foot area were exposed to direct wind pressure and gave the formula:

$$p = \cdot00475\ SV^2.$$

The value of the constant in seven of the published results ranged from ·0039 to ·0054. The mean of the seven agrees very closely with that of Rouse.

Recent Experiments.—Experiments have been tried in France on the resistance of the air to flat boards, suspended laterally from a train, movable on axles and counter-weighted. The results have been given in the Railroad and Engineering Journal for February, 1887. The train was run at increasing velocities and the instant was noted when the resistance of the air, preponderating, caused the lifting of the weight and reversal of the board. The resistance on a plate a decimeter square, in absolutely calm weather, was found to be ·52 kilogram, at a speed of 44·5 miles per hour. The data give:

$$p = \cdot 00535\ SV^2.$$

For other velocities the variation is sensibly as the square of the speed; and within practical limits the *extent* of the surface does not sensibly affect the result.

Theoretical formula.—Prof. Unwin in the "Encyclopædia Britannica," in the article Hydromechanics, at p. 517, gives the following formula for the resistance encountered by a thin plate moving through the air, or through an indefinitely large mass of still water, in a direction normal to its surface

$$R = f\,G\,S\frac{V^2}{2g}.$$

In this: R= total resistance, expressed in pounds, due to an excess of pressure in front augmented by an increase of pressure due to a partial vacuum in the rear of the plate; f= a coefficient to be determined by experiment; G = density of the fluid; S= surface of plate in square feet; V= relative velocity of fluid and plate in feet per second; g = force of gravity. For a plate moving in still fluid, f=1·3, and for a current impinged upon a fixed plane it is 1·8, whether the fluid be air or water. Prof. Unwin thinks this difference is, perhaps, due to errors in the experiment. Thibault, with plates of 1·17 to 2·50 square feet area, exposed to wind pressure, found f to vary from 1·568 to 2·125, the mean being 1·834. Using this value for f, and making the proper substitution in the above formula, we find by our notation,

$$p = \cdot 00496\ SV^2.$$

It will be noticed that Prof. Unwin's description of Thibault's researches differs slightly from that already given, presumably of the same experiments. The latter were taken from a translation of Morin's mechanics and may be in error. Prof. Unwin finds that all experiments with whirling machines have shown a steady increase of resistance per square foot with the

larger plates, and he thinks this is due to the centrifugal action which causes a flow of air outward across the plate.

It will be readily seen that there is a great difference between the results with small plates on whirling machines and those with direct wind pressure. The results with an arm of 16 feet, when compared with those of shorter arms, seem to indicate that the increase of pressure per square foot, with the larger plates, is due to centrifugal action, as suggested by Prof. Unwin, though it is probable that the effect is complicated, in almost all the results thus far, by the breaking up of the partial vacuum in the rear, thus tending to diminish the total pressure; and in a contrary direction, there is a tendency to increased resistance, especially in small rooms, from the fact that the air does not have a perfectly free escape to the rear, owing to the nearness of the walls. The constant for the arm of 16 feet is much less than that with the straight line motion, though it would seem as if it should be nearly the same. Possibly the partial vacuum in the rear of the plate is somewhat diminished, but more important, probably, is the low velocity employed, as with the four inch plate the velocity was seven miles per hour, but with the 24-inch plate (which had a resistance of ·33 pound) the maximum velocity was only four miles per hour. It is impossible from such results to reason to velocities ten times as great. Examining Thibault's results, we find two of them agreeing very nearly with those with the 16 foot arm, and it may be that they were dependent on a small wind velocity.

It seems necessary to carry on experiments at much higher velocities, but not with a whirling machine, though higher velocities with arms of 20 or 30 feet would undoubtedly give interesting results. The most feasible method would seem to be with a locomotive pushing two or three platform cars loaded with iron, the plates or other resisting forms to be exposed on the front car. By this means all interference from the locomotive or train would be obviated, and it would be easy to obtain results up to 40 and more miles per hour.

Conclusions.—1st. In obtaining the relation between wind pressure and velocity, the use of whirling machines with arms much less than 16 feet (radius) will tend to give unsatisfactory results, owing to centrifugal actions and to irregularities in the resistance of the air due to the formation of eddies, etc., especially in small rooms.

2d. The increase of total pressure per square foot, with the larger plates, as found by so many experimenters, is mostly due to the shortness of the arms employed, and disappears with an arm of 16 feet and in straight line motion.

3d. For velocities up to seven miles per hour with small

plates, and up to four miles per hour with larger plates, the relation between the pressure and velocity may be expressed by the formula,

$$p = \cdot 0034\ SV^2.$$

In this, p=pressure in pounds: S=surface in square feet: V= velocity in miles per hour.

4th. Experiments are much needed, with larger plates than two feet square, with bodies of other forms, and with high velocities by a straight line motion.

No attempt has been made in this paper to give a summary of anything more than what appeared to be the better class of results in this field. It is believed enough has been given to show which results are the more reliable, and how much necessity there is for further research.

Experiments with an anemometer.—One of the more important questions in connection with the use of Robinson's anemometer is the determination of the relation between the velocity of the wind and that of the cups. This relation has been assumed to be about 3, i. e., three times the velocity of the cups equals that of the wind. Some experiments in England with large anemometers as compared with smaller, have shown that if the former have a velocity of 2·5, the smaller would need a coefficient about a fifth larger to give the true velocity. The earlier anemometers used in this country were rather clumsy and unsatisfactory. A form was devised by Lieut. Gibbon (Signal Service), after experiments with an electric register of the actual revolutions, and a comparison with that form of wheel register which gave the result nearest to that of the electric count. This form has never been tested for its coefficient, so far as can be learned, hence a few observations were made on the 16 foot arm. The anemometer used was nearly new, having been run only 1,500 miles, was carefully oiled and in most excellent condition. The cups were 4 inches in diameter, and their distance from the axis 6·72 inches. The highest velocity attained was 12 miles per hour. The values of the coefficient in five sets were 2·92, 3·06, 2·84, 2·98, and 2·92, giving a mean 2·94 instead of 3·00, the one now in use. It should be noted that, intentionally, there was introduced a tendency toward a too small value, for, after the cups had acquired a momentum, toward the end of the experiment, the bar was stopped rather abruptly, but the cups were allowed to come to rest of their own accord. Experiments on this question are still needed with a rectilinear motion and with much higher velocities.

Washington, April 20, 1887.

ART. XXVIII.—*Is there a Huronian Group?* by R. D. IRVING.

[Continued from page 216 of last number.]

IV. Deciding that the type Huronian is a true group is a very different matter from concluding that all rocks which have been called Huronian in other regions are the geological equivalents of the type series. On the contrary, even in the Lake Superior region, and by members of the Canadian Survey itself, there have been referred to the Huronian most diverse formations. Some of these seem properly enough so referable; others as surely are not so referable, while as to the reference of still others there must remain very much doubt. A discussion of those correlations which have been attempted between the type Huronian and the rocks of distant and always disconnected geological basins would be of little utility. Unsupported lithological evidence only is available for such correlations, and, in point of fact, with most, if not all of those who have attempted these distant correlations there has prevailed a most singular misapprehension as to the real nature of the type or original series. For this misconception Dr. T. S. Hunt seems to be mainly responsible, he having steadily represented the type series to be a truly crystalline one, and as composed of highly folded crystalline schists, mainly chloritic slates and schists.* *Yet there is no such series of rocks in the original or type area*, whatever may be true of other regions whose rocks have been called Huronian.

Not to concern myself then with these distant correlations, in which I am able to feel but little confidence, I wish next to consider briefly how far the rocks of other districts in the region of Lakes Huron and Superior may be correlated with the type Huronian.

For the establishment of such correlations we have of course no fossils, and must depend on the lithological characters and subordinate stratigraphy of the rocks whose reference to the type series is to be discussed, as also on their structural relations to adjoining rock groups. There is good reason to believe that in the region which stretches from the north shore of Lake Huron to the Mississippi River we are dealing with one geological basin, so far as the rocks which I take to be the equivalents of the type Huronian are concerned; in other

* "A great series of chloritic slates and conglomerates with interstratified greenstones, quartzites and limestones," Azoic Rocks, p. 70; "group of chloritic slates with greenstones and quartzites," ib. p. 72; "the younger and unconformable series of crystalline rocks found on the shores of Lake Huron," ib. p. 72; "the contrast between the highly disturbed condition of the former [Huronian] and the broad folds and gentle dips of the Montalban," ib. p. 215.

words, there is good reason to believe that all of these areas were once connected, the connections having since been removed by erosion. Hence the correlation of these different areas by lithology, stratigraphy and structural relations to adjoining groups is not so entirely unlike the use of these same criteria in tracing one of the fossiliferous groups from point to point.

Proceeding westward now from the type Huronian area, all the pre-Cambrian rocks are concealed, either by the waters of Lake Superior or by the overlying horizontal formations of the eastern part of the Upper Peninsula of Michigan, until the vicinity of Marquette, on the south shore of the lake, is reached. Here a belt of much crumpled, generally steeply inclined and partly schistose strata reaches the lake coast, with a width on the shore line of about five miles. The coast of the lake here has a nearly due northerly trend, facing eastward. The course of the rock belt referred to is at right angles to this, that is, it lies east and west. Followed westward the belt is found at first to expand to a width of some twelve to fifteen miles, and then to contract again, until at the eastern end of Lake Michigamme, thirty miles west of Lake Superior, it is little more than two miles wide. Still farther west it expands over a large area, whose limits can hardly be said to be as yet determined.

North and south of this belt are large areas of granitic and gneissic rocks. Two widely divergent views have been held with regard to the relations of these granites to the schists between them. The earlier writers on the region, and especially Messrs. Foster and Whitney, in their classical report, held that the granites were of eruptive origin, and of a date subsequent to the formation of the various stratiform rocks, whose crumpled and disturbed positions these geologists were disposed to assign to the eruption of the granite masses on either side of the trough. Later, on account of the arguments of Kimball, Murray, Brooks, etc., the view came to be generally held that the granitic and gneissic rocks represented the ancient Laurentian basement, upon which *all* of the stratiform or Huronian rocks were deposited unconformably; that, the whole region having been subsequently affected by a lateral pressure, the sedimentary rocks were pushed into folds, and that the granitic rocks on either side were brought to the surface by denudation. Recently the older view of Foster and Whitney has been advocated by Dr. M. E. Wadsworth* and Dr. C. Rominger,† both supporting it by an appeal to intrusions of the schistose

* Bulletin Mus. Comp. Zool., vol. vii, No. 1, 1880.
† Geological Survey of Michigan, vol. iv.

rocks by the granite. It is true of course that these granitic intrusions might be in part quite independent of, and of later date than the great granitic masses; but, as Dr. Rominger argues, and as our own observations have abundantly shown, these intrusions of the schists along their contacts with the granite are so plentiful in certain parts of the region that it seems necessary to conclude that such invaded schists are older than the great granitic masses themselves. On the other hand, we have found certain of the contacts of the stratiform rocks with the granite to present admirable examples of basal conglomerates, the granitic and gneissic rocks having evidently been beaten upon and broken down by the sea in which the other rocks were laid down.

These entirely contradictory appearances seem, however, to find a very simple explanation in the view that the stratiform rocks themselves are, in fact, made up of two entirely distinct sets;* an *older* series of very intensely altered and crumpled true crystalline schists, in the main of a greenish color, which are invaded intricately by the granite at their contacts with it; and a *newer*, feebly altered, mainly fragmental series, whose contacts with the granite and the schists of the older basement are such as to render the intervening structural break very evident. The contrast between these two sets of stratiform rocks as to degree of alteration, and as to the penetration of the one set by the granite while the others show no such penetration, was partly realized by Dr. Rominger, and is plainly stated in his report on the northern peninsula of Michigan, in which, however, he yet regards the granite masses as newer than all the stratiform rocks of the region, the high degree of alteration of the schists penetrated by them, as compared with the smaller degrees of alteration of the higher strata, being explained by the greater proximity of the one set to the granite. In the same report Dr. Rominger shows, however, that the relatively unaltered strata often come directly in contact with the granite, in which case they present a peculiar appearance suggesting to him a slighter alteration by contact with the eruptive masses. The peculiar granitoid quartzites which he takes to have been produced by the metamorphosing action of the granite are plainly, however, merely detrital derivatives from the granite, and often run into coarse bowlder-conglomerates, as Dr. Rominger himself now realizes and states.† However, neither he nor any other writer on this region seems to have realized heretofore that the clue to its geology lies in the separation of the stratiform rocks into two entirely distinct and mutually discordant series.

* As first suggested by myself in 1883, (Fifth Annual Report U. S. G. S., p. 190) and more definitely announced in 1884.

† Unpublished MS. report on the Geological Survey of Michigan, 1884.

The proofs of this distinctness are analogous to those which establish the separateness of the type Huronian, of Lake Huron, from the adjoining crystalline schists, viz: (1) a general lithological contrast between the two series concerned, the one being mainly but little altered, the other highly crystalline and schistose; (2) visible discordances in a few places on the contacts of the two sets of rocks; (3) the penetration of the lower strata by granite veins and masses which fail to penetrate the higher detrital rocks, but on the contrary have yielded fragments to them; (4) the development of true basal conglomerates at the contacts of the two series; and (5) the fact that the higher detrital rocks are in contact with different members of the lower series.

Nevertheless there are presented here some differences from the conditions observable on the north shore of Lake Huron, which serve to obscure the true relations of the different rocks. The placing together of all of the stratiform rocks of the Marquette belt by most geologists is not at all to be wondered at, for here the newer detrital rocks have been subjected to a much greater lateral pressure, and are consequently much more highly inclined and closely folded; besides which this closer crumpling has at times developed a tendency to a transverse cleavage accompanied now and then by the development of some of the micaceous minerals which are so frequent accompaniments of pressure metamorphism. Thus the evidence under the first of the heads just named is in part obscured, more especially through the development from fragmentals of certain mica-schists, though the essential lithological differences between the two sets of rocks become distinct enough on closer inspection.

A more important obscuration of original conditions applies to the evidence under the second head. Discordances are very plainly to be seen in a few places,* and perhaps in general the higher series lacks the high inclinations of the lower; still there are many places where its inclinations are very high, and where the common pressure, to which both underlying schists and overlying detritals have been subjected, has made them nearly or quite parallel. This apparent obliteration of unconformity is yet more marked in some of the districts subsequently to be noted. To render the case still more difficult of comprehension, the denudation which has so deeply truncated the region has occasionally brought to light within the area occupied by the newer detrital strata patches of the older schistose basement; which patches, sometimes completely surrounded, or bordered closely on either side by the newer fragmentals, it has seemed necessary to regard as parts of the same

* As for instance on the N.W. ¼ of sec. 1, township 47, range 24 west, south of Marquette.

formation with them. The matter has been yet further complicated—though this difficulty mainly disappears on microscopic study—by a resemblance, partly close and partly only macroscopic or very vague, between certain of the older schists that have been produced by the intense squeezing and alteration of some sort of basic eruptives, and certain interleaved basic eruptives of the upper series. Again, some of the later basic eruptives have intruded indifferently the detrital areas and those of the older schists. Notwithstanding these difficulties, and the fact that there may be with regard to some particular exposures doubt as to whether they should be referred to one or the other series of rocks, it remains sufficiently evident that there are the two distinct sets of rocks in the Marquette region.

The *upper* series is mainly composed of detrital rocks usually little more altered than in the Lake Huron Huronian; the most abundant being quartzites. These are of various phases, ranging from the most vitreous quartzite to only slightly indurated sandstone; but all are genuine fragmental rocks. A clayey admixture is often present, and then at times pressure has developed a schistose structure and a secondary sericitic ingredient; but even in this case there is no difficulty whatever in detecting the essentially fragmental character of the rock. By increase of this clayey ingredient we have a gradation into the clayey shales and slates, which form the next constituent of the series in order of abundance. These present many phases, ranging from arenaceous to earthy in texture; being at times cross-cleaved and again not so, when they are little more than clay shales. They include also some very highly carbonaceous kinds. Next to the detrital rocks in importance, and presenting often gradation phases into them, is a series of what we may speak of as chemical sediments, though these have often undergone very great changes since their first deposition. Here belong the various calcareous and dolomitic rocks, the cherty or jaspery ferruginous schists and iron ores, and the actinolitic ferruginous schists. Most, if not all, of these ferruginous rocks have been derived from bedded iron carbon-

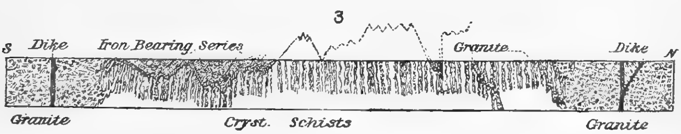


FIG. 3.—Generalized ideal section of the Marquette region in the vicinity of Marquette, showing the relations of the younger detrital rocks to the older granite-invaded schists. Scale, 2 miles to the inch.

ates by a process of silicification, as I have endeavored to show elsewhere, the unaltered or little altered iron carbonate at

times remaining in considerable bodies. Besides these two classes of sediments, or alteration derivatives from sediments, there are included also considerable thicknesses of diabasic greenstones in the shape of eruptive sheets. These are of

4

FIG. 4.—Generalized ideal section of the Marquette region in the vicinity of Ishpeming. In part after Brooks. Scale, 3 miles to the inch.

course irregularly distributed, being almost absent on some sections, and especially abundant on others, as for example on the Ishpeming section herewith. West of the area mapped, in the vicinity of Lake Michigamme, micaceous slates and micaceous quartzites make up a considerable thickness in the uppermost horizons of the series. These are often deserving of the name of mica-schist, approaching very close to if not quite reaching, the character of a genuine crystalline schist; but they run into kinds that are plainly detrital even to the naked eye. They have apparently been produced, as have the mica-schists of the Penokee region, by metasomatic processes, from detrital rocks holding much fragmental feldspar; but in this case, unlike that of the Penokee country, there has been strong lateral pressure involved and something of a genuine foliation has been produced. These schists and slates do not seem to be persistent, i. e., they are represented stratigraphically in other portions of the district by unaltered detrital rocks.

The accompanying map* and sections will serve to show the distribution and relations of the granite, older schists and younger iron-bearing series, for a distance of some five and twenty miles westward from Marquette. Since the idea of a separation between the older and newer rocks receives so great support from the occurrence of basal conglomerates, I have indicated on the map by letters the points at which the most unmistakeable occurrences of this kind have been met with, omitting all cases about which there seemed to me to be any question. It will be observed that the places indicated furnish points on each side of each of the detrital areas. In one case, as for instance, that on the east line of Sec. 2, T. 47, R. 25 W., we have merely a fine detritus from the contiguous granite; but in most cases large blocks and pebbles of granite, gneiss

* This map is not here reproduced. It was a large outline geological map, in colors, of townships 47, 48 and 49, ranges 25, 26, 27, 28, in Michigan, drawn to a scale of 1·5 miles to the inch, and showing the distributions of (1) the detrital iron-bearing rocks, (2) the older schists, and (3) the granite which invades the older schists at its contacts with them.

and schist occur in the slate or quartzite at the contact. The occurrences on the S.E. $\frac{1}{4}$ of Sec. 29, T. 48, R. 25 W., only about three miles west of Marquette, and those in Sec. 22 and adjoining sections of T. 47, R. 26 W., south and southwest from Goose Lake, are very striking; but possibly those in sections 8 and 19 of T. 49, R. 28 W., in the vicinity of Silver Lake, are yet more so. In this vicinity the older rocks, consisting of granite and schists involved with one another in such a way as to render irresistible the conclusion that the granite has intruded the schists, form a bold range sloping abruptly down to a lower area occupied by the softer detrital rocks. At the foot of the granite range the detritals, in contact with the granite and schists, are found crowded with fragments of both, of all sizes, up to pieces several feet across. The fragments are partly angular, lying in a breccia against the granite, and partly well-rounded. Since the granitic fragments represent a rock which, according to the present state of lithological science, could only have formed at great depths, and since the schists, whatever their first origin, must have received immense alterations by pressure before yielding fragments, we are forced to believe in a period of extended sub-ærial erosion intervening between the times of first formation of the older and newer rocks.

If we proceed in a direction southward from the Marquette region, we traverse great areas underlain by the granites, gneisses and schists of the older formation, but when the Menominee River is reached, at the boundary of Wisconsin and Michigan, we have crossed also at least four distinct belts occupied by the rocks of the newer or iron-bearing series. According to the mapping of the Michigan geologists these several belts merge, farther westward, into a single extended area of the iron-bearing series. It seems certain that this formation has a wide spread in that direction, but just what the relative extents of the older and newer rocks in this direction are, remains to be shown by further exploration. Of the several belts crossed by a line running south from the Marquette

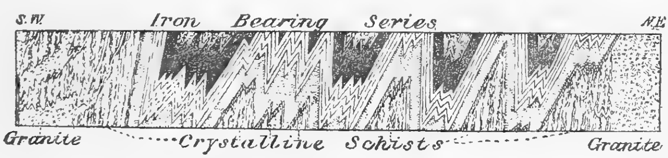


FIG. 5. Generalized ideal section of the Menominee Iron Region. Scale, 3 miles to the inch.

belt to the Menominee River, that one skirting the Menominee River on its northern or Michigan side and run-

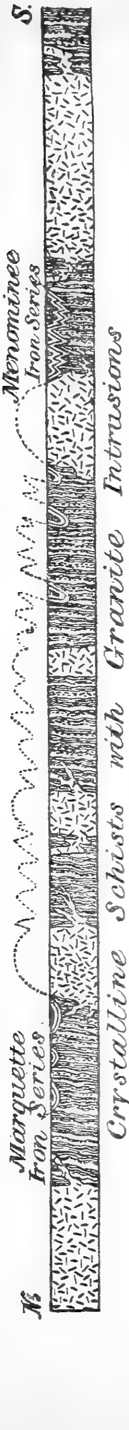


FIG. 6. Generalized ideal section of the Menominee and Marquette regions and intervening territory. Scale, 10 miles to the inch.

ning thence north of west into Wisconsin, is the most extensive. The accompanying section is designed to represent the general relations of the two formations and the nature of the folding of the strata in this region. As in the case of the sections of the Marquette region, this one also has been drawn to a scale after a careful study of all the facts hitherto published, and of those gathered by ourselves. The two formations concerned are manifestly identical with those of the Marquette region. We have here again to do with an upper, relatively little altered, iron-bearing series, and a lower, deeply altered series of gneiss and schists with immense areas of intrusive granite. The principal point of difference between the two regions lies in the much closer folding that the Menominee rocks have received. Had the section been made farther west, a larger thickness of the Huronian strata would have been shown, and other folds would present themselves.

All the arguments that applied in the Marquette region in favor of the existence of a discordance between the two formations, apply here again. The basal conglomerates of this series are particularly finely developed, and may be seen on a grand scale at the contact of the basal quartzite with the granite at the falls of the Sturgeon River.

The several belts that intervene between the one just described and that of the Marquette region, are much narrower, but nevertheless seem to contain as great a thickness of the iron-bearing formation. In the case of the Felch Mountain belt, which does not exceed a mile in width, all of the strata are described by Dr. Rominger as dipping at a high angle to the northward, and in crossing the belt from the south to the north, after passing the middle, one traverses a repetition of the belts crossed farther south, but in an inverted order. It would seem that we have to do here with a case of a synclinal whose sides are folded close together. Fig. 6 shows in a general way the supposed relations between the older rocks and the several belts of the newer series in the relatively little known area between the Marquette region and the Menominee River.

Passing now over a good deal of intervening territory, where the same two formations, however, continue to display themselves, I ask your attention next to the Penokee region of Northern Wisconsin and Michigan.

Here we find a most notable instance of an unconformity between a series of highly tilted but unfolded strata above the break, and a deeply folded series below. Indeed, there are in this region two striking stratigraphical breaks; one between the iron-bearing series and the folded gneissic formation to the south of it, and another between the unfolded but highly inclined iron-bearing series and the equally highly inclined Keweenaw series to the north. The accompanying map and sections* show the distribution and structural relations of the several formations and the several principal kinds of rock in this region. The Keweenawan and iron-bearing rocks both being highly inclined, the map is in fact what the vertical section is where the upper strata of an unconformity are essentially horizontal. The region is one which is only now beginning to be at all easy of access and it is still in the main covered with a dense forest growth. Notwithstanding these difficulties, and the further difficulty that in places the drift-covering is considerable, the general structure of the region has been by a great deal of painstaking labor pretty thoroughly worked out.

The lower one of the two unconformities of this region, i. e. that between the gneissic formation on the south and the iron-bearing series next north of it, is established by the same phenomena as those appealed to in the case of the region of Lake Huron. These are (1) the traversing of the lithologically distinct areas of the older or basement formation by the continuous belts of the higher series, as is most beautifully shown by the accompanying map; (2) the intersection of the schistose rocks of the older series by granite masses and areas which have yielded fragments to the higher series; (3) the occurrence in the higher series of fragments derived from the stratiform members (gneiss, mica schist, etc.), of the lower complex, these fragments occurring in beautifully developed basal conglomerates at the contact of the two sets of rocks; (4) the striking lithological contrasts of the two sets of rocks, the bedded members of the lower set having arrived at a nearly complete

* Not here reproduced. The map displayed when the paper was read was a colored one some twelve feet in length, showing the distribution of the iron-bearing rocks, the older schists, the granites invading these schists, and also in part of the Keweenawan Rocks of the region. This map with its accompanying sections, has already been published in a reduced form in this Journal for April, 1885. In a very much improved form it will appear also in the seventh annual report of the U. S. Geol. Survey, and in a forthcoming memoir on the Penokee-Gogebic region.

re-crystallization, while the upper series is composed mainly of but little altered fragmentals; (5) the highly foliated, folded and contorted condition of the lower rocks as contrasted with the unfolded and unfoliated condition of the higher. Any one of these would alone raise a strong presumption in favor of the existence of a great break at the junction of these two series of rocks; together they seem to amount to a demonstration of chronological distinctness.

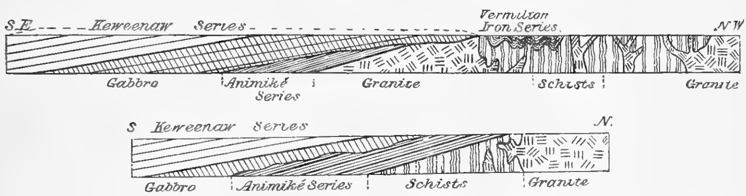
North of the narrow belt of country occupied by the iron-bearing series in this region, and all the way to the shores of Lake Superior, the rocks of the Keweenaw series are at surface, with the exception of a belt of country in the vicinity of Chequamegon Bay, which is underlain by the Potsdam sandstone, and a small area in the vicinity of the Presqu'Isle River, which is again occupied by the same formation. This sandstone, as is well known, traverses the upturned edges of the Keweenaw series in many places. It will not be possible now for me to review the nature and general structural characters of the Keweenawan rocks of this region. I can only say that the series consists of a great succession of eruptive flows, alternating with which are beds of detrital material, and following which is an immense thickness of sandstone. In the vicinity of the iron-bearing rocks these layers stand at high angles, and present in strike and dip a general conformity with the layers of the iron series itself. But a closer inspection renders it evident that the upper surface of the iron-bearing series has suffered a deep erosion previous to the spreading upon it of the great flows of which the lower portion of the Keweenaw series is made. This is shown by the very striking manner in which these flows are found in contact with all members of the iron-series as the contact line is followed from east to west.

Thus in the Marquette, Menominee and Penokee districts there are great discordances between a *lower* set of gneisses and other crystalline schists, intruded by granite, and an *upper* set of detrital rocks, carrying iron. In all three districts, moreover, the two sets of rocks seem so manifestly the same, being, indeed, very probably directly continuous through all, that we can hardly doubt that in all of these districts we are dealing with the same discordance. Above the uppermost of these series succeeds the great Keweenaw complex, while the Potsdam sandstone traverses indifferently the eroded edges of all three of these groups of strata.

If now, grouping these three districts in one region, we compare their succession with that of the Lake Huron region, we find such a striking similarity as to the relations and natures of

the members of the successions in the two regions, that little doubt can remain as to the equivalency of these members, each to each. In each region we start with a great basement complex of crystalline schists, gneiss and granite, upon whose immensely denuded upper surface reposes a great quartzitic and slaty detrital group, carrying sheets of chemically deposited iron and lime carbonates. In each region this is succeeded in turn, but with an intervening discordance, by the great Keweenaw series; while above this again follows the Potsdam sandstone.

V. I will next ask your attention to the relations borne by the so-called Animiké series to the older schists and granites of the region north of Lake Superior. These relations furnish us with an excellent instance of an unconformity in which the upper series has been tilted into an inclined position since its original accumulation, but in which the amount of tilting has not been great. In other words it is a case where the conditions are not greatly different from those obtaining when the upper formation above an unconformity has remained horizontal.



FIGS. 7 and 8.—Generalized and partly ideal sections of the northeastern part of Minnesota. Scale, 16 miles to the inch.

The accompanying map and sections show* in a general manner the geology of this region as known to date. Since this map is in large measure based on hitherto unpublished material, and since the geology of the area it represents has been heretofore, so far at least as the interior is concerned, largely conjectural, it is desirable that I should give here somewhat more of an account of the structure of this region than would otherwise be necessary.

* The sections only are here given, on a greatly reduced scale. The map displayed to the Academy was a large colored one, drawn to a scale of four miles to the inch, of all of that portion of the United States north of Lake Superior, and east of the upper Mississippi; showing the distributions of the Potsdam sandstone, of the Keweenaw series and of the great gabbro at its base, of the Animiké series, of the Vermillion Lake iron-bearing rocks and of the older crystalline schists, with the great granite and gneiss areas whose contacts with the schists appear to prove the former the newer rocks. This map, embodying the latest geological and geographical information, is now in press for the Seventh Annual Report of the U. S. Geological Survey.

The latest formation of the region is the *Potsdam sandstone*, which shows in the extreme southwestern corner of the area mapped, in the vicinity of the St. Louis River, between Fond du Lac and Thomson, Minn. The sandstone, here of a generally reddish cast, and with a slight easterly dip, may be seen directly overlying a series of folded and cleaved slates belonging in the upper part of the Animiké series, as subsequently explained. The contact of this sandstone with the Keweenawan rocks, which are largely displayed in the vicinity of Duluth, is concealed; but in Douglass County, Wis., at a distance of ten or fifteen miles southeast from Fond du Lac, the sandstone may be seen in very distinct unconformable abutment against the Keweenawan diabases of that district. Farther east the entire coast of Lake Superior, to within two miles of the mouth of the Montreal River, on the boundary line between Michigan and Wisconsin, is formed of the same sandstone in a horizontal position.

Unconformably beneath the Potsdam sandstone comes next the great *Keweenaw series*, which in this region reaches an aggregate thickness of upwards of twenty thousand feet, the layers being mainly of an eruptive origin, but also in part of a detrital nature. The upper detrital division* of the Keweenaw series is, however, not represented in the region, being buried here beneath the waters of Lake Superior. So far as the coast line of the lake is concerned, the characters and divisions of the Keweenawan rocks there displayed, I have set forth elsewhere.† Much new material has since been gathered with regard to these rocks in the interior of this region, but I will take the time now only to note their general flat lakeward dip,‡ the concentric and crescentic curves of the outcrops of the beds or groups of beds—the highest layers appearing on the Minnesota coast about midway its length—and the immense development of coarse grained, stratiform olivine-gabbro at the base of the series. These gabbros are the surface-rocks over an area in the interior some 125 miles in length from northeast to southwest, 25 miles in greatest width, and considerably more than 1,000 square miles in extent.

Next in downward order comes the *Animiké iron-bearing slaty series*, whose relations to the adjoining formations it is now designed especially to set forth. These Animiké rocks are exposed in four distinct areas, one of which is separated from the others by an overlap of the great gabbro which forms the base of the Keweenaw series. The others are separated

* See Monog. U. S. G. S., vol. v, pp. 152 and 266.

† Copper-bearing Rocks of Lake Superior, Monographs of the United States Geological Survey, vol. v, pp. 260–328 and Plates I–III, V–XV, XXVI, XXIX.

‡ Monog. U. S. G. S., vol. v.

from each other, so far as known, by drift covering only. The first of these areas is that which, with its principal development in Canada, along the shores of Thunder Bay, crosses into the United States in northeastern Minnesota, the national boundary line being within this formation from the outlet of Gunflint Lake eastward to the eastern extremity of Pigeon Point. Around Thunder Bay the rocks of this series, which are chiefly black slates, greywackes, and argillaceous quartzites, with interstratified diabase and gabbro layers, are exposed on a large scale. Immense dikes of gabbro and diabase also penetrate these layers, the gabbro dikes, which are at times several hundred feet in thickness, being noticeably much closer in character to the great gabbro at the base of the Keweenaw series than to those gabbros which are interleaved with the Animiké slates.

In the vicinity of Thunder Bay the Animiké rocks are often nearly horizontal, but show a general tendency toward a south-eastward inclination. As the formation crosses into United States territory it shows more marked inclinations, whose amounts average probably about ten degrees, though at times less than this, and again reaching as much as twenty degrees. As already said, the national boundary line is situated within this formation from the mouth of Pigeon River to Gunflint Lake, but on the north side of the latter lake, and again to the north of the next lake to the east, called North Lake, the unconformable abutment of the Animiké series against an older formation of granite and schists is very handsomely shown. The actual contact of the two formations is not seen, but the exposures approach to within a few feet of each other, and their relative attitudes are such as to leave no question whatever with regard to the unconformity. Not only is this shown by the vertical position of the schists as contrasted with the flat inclinations of the slaty series, but also by

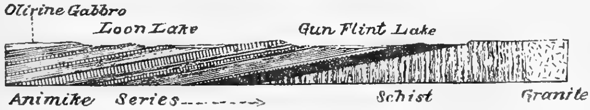


FIG. 9.—Section across Gunflint and Loon Lakes, on the national boundary line. Scale 1½ miles to the inch. Designed to show the relation of the Animiké series to the older schists and granite, and to the newer Keweenawan gabbro. Scale 1 mile to the inch. The black bed at the base of the Animiké is the ferruginous horizon. The remainder of the Animiké in the section is composed of slates and slaty quartzites with interstratified greenstones.

the way in which the latter beds, to the north of the two lakes mentioned, fit into the sinuosities of outline of the older formation. The entire contrast as to lithological characters between the two sets of rocks furnishes further proof. A north

and south section midway in Gunflint Lake is given herewith to illustrate these relations. So far as it is developed along the national boundary line the lowest layers of the Animiké series in sight are those on Gunflint Lake. The highest layers are those in the vicinity of Grand Portage Bay, the whole succession between these points being some thousands of feet in thickness. The iron-bearing horizon at the base of this succession is lithologically identical with that of the Penokee series of northern Wisconsin and Michigan, while the black slates, greywackes, etc., which succeed the iron-bearing horizon are in turn the counterparts of those which form the middle and upper portions of the Penokee series. The interstratified gabbros of the Animiké are wanting, however, or are relatively rare in the Penokee region.

In attempting to trace the Animiké rocks from this area farther west than southwest we find ourselves constantly balked by the overlapping layers of the Keweenaw series. This overlap will be best appreciated on an inspection of the accompanying map, upon which it is shown that the basal olivine gabbros of the Keweenaw series entirely cut out the Animiké in its surface distribution, coming, a few miles to the northward of Gunflint Lake, directly into contact with the older schists. Continuing southwest nothing farther is seen of the flat-lying Animiké beds for over fifty miles, but in the vicinity of the south side of Birch Lake they emerge from beneath the overlapping gabbro. From here the lower members of the series, with the usual flat southeasterly dip, and with the lithological characters well-preserved, may be traced along the south side of the Mesabi granite range as far as the Embarrass Lakes, a distance of some twenty-five miles; in which distance they are plainly in unconformable abutment upon the granite to the north. After this they are concealed entirely, so far as present knowledge is concerned, by the immensely heavy drift-covering of the region, until the vicinity of Pokegama Falls on the Mississippi River is reached, some sixty miles farther to the southwest. Here the basal layer of the Animiké is a reddish quartzite followed by, and associated with, layers of cherty iron ores like the remaining ones of the Animiké series. These layers dip at the usual flat angle to the southeastward and rest unconformably upon gneiss and granite, which are plainly the direct continuation of those of the Mesabi range.

Southward and eastward of the line from the Mesabi range to Pokegama Falls the rocks are mainly concealed by swamp or heavy drift covering, but a great display of the upper portions of the Animiké series is seen again along the St. Louis River from Knife Falls to Thomson, where they are cleaved

and folded argillaceous slates. Farther south and west these slates may be traced into continuity with mica-schists, which, on the Mississippi River, in the vicinity of Little Falls, are staurolitic and garnetiferous. These upper horizons of the Animiké are the counterparts of the upper horizons of the iron-bearing series in the Penokee region and again in the Marquette region of Michigan.

The Animiké rocks of this region are thus conformably placed upon an older series of schists and granites, and lie unconformably beneath the newer Keweenaw series, the latter unconformity being indicated by the manner in which the basal beds of the Keweenaw series traverse the courses of those of the Animiké, and by the folded condition of the Animiké slates in the vicinity of the St. Louis River; the crumplings in this case having plainly preceded the accumulation of the Keweenawan beds.

Thus the Animiké series occupies very plainly the stratigraphical position of the original Huronian, and of the various iron-bearing groups of the south shore of Lake Superior. Since it is also intrinsically so extraordinarily like the Penokee series as to leave no doubt of their identity; and since the Penokee is as evidently the equivalent of the original Huronian, we seem to be left no choice as to calling the Animiké Huronian also.

[To be continued.]

ART. XXIX.—*Oxygen in the Sun; Contributions from the Physical Laboratory of Harvard University;* by JOHN TROWBRIDGE and C. C. HUTCHINS.

[From the Proceedings of the American Academy of Arts and Sciences, vol. xxiii; Investigations on Light and Heat, made and published wholly or in part with Appropriation from the Rumford Fund. Presented March 9, 1887.]

SINCE the time it was announced that hydrogen existed in great abundance in the sun's atmosphere and was a controlling element in its economy, there have been no more interesting questions in solar physics than those touching the presence of other gases in the sun's body and atmosphere; and when we consider the important part that oxygen plays in terrestrial affairs, the great variety of combinations into which it enters, and its high constituent percentage in the composition of the earth itself, a peculiar interest, second to that of no other element perhaps, attaches to its probable presence in the sun.

The investigation of the spectrum of oxygen as a research by itself, and as connected with its presence in the sun, has occupied many eminent physicists; but the fact that the latest

and most complete investigations have left the minds of scientific men still in doubt, has led the writers to take up the question again with more perfect and powerful apparatus and increased facilities, in order if possible to add something to the knowledge of the subject.

The question of the existence of oxygen in the sun was first seriously investigated, we believe, by Dr. Henry Draper, who published in the American Journal of Science for 1877 and 1879, and in foreign journals, papers accompanied by reproductions of his photographs. Dr. Draper was firmly persuaded of the existence of oxygen in the sun's atmosphere, and based this belief upon the apparent coincidence of the lines of oxygen taken in air with certain bright spaces in the sun's spectrum which appeared upon his photographs.

Prof. John Christopher Draper published a paper in the American Journal of Science for 1878, in which he stated his conviction that oxygen exists in the sun; but his line of argument was just the reverse of that of Dr. H. Draper. While the latter apparently proved the existence of oxygen in the sun by the coincidence of its bright lines with bright spaces in the solar spectrum, the former was led to believe that the bright oxygen lines coincided with dark lines in the sun.

Both observers abandoned the old method of eye observation, and took advantage of the improvements in photography to record the oxygen lines upon a sensitive plate. Dr. H. Draper was led to abandon Geisler's tubes filled with oxygen, and to employ the electric spark in common air, on account of the greater brilliancy of the lines, while Prof. J. C. Draper still adhered to tubes filled with rarefied oxygen. The oxygen lines had been mapped by previous observers, notably by Thalen, and Schuster had shown that there were four spectra of oxygen which could be produced under varying conditions of temperature and pressure.

The photographs of Dr. Henry Draper's oxygen spectrum, together with the juxtaposed solar spectrum, were submitted to the French Academy of Sciences in Paris, June 23, 1879, by M. Cornu. From the remarks of M. Faye we make the following extract:—

"Dr. H. Draper has, however, succeeded in discovering oxygen, not in the chromosphere, but in the photosphere, where it discloses itself by bright lines. It is obvious that this gas is dissociated at a depth, and is immediately taken up by multiple combinations in the region and at the temperature of the brilliant surface. I see in these facts the hope of a confirmation, and above all of an extension, of the views I have put forth on the constitution of the sun; but whatever may be the fate that the progress of spectrum analysis reserves to them,

I express here my admiration for the discovery of Mr. Draper, and I hope that his results, so well confirmed by the photographic proofs that our learned member, M. Cornu, has shown the Academy, will not delay in being universally accepted by competent judges."

The opinion thus expressed by so eminent an authority as M. Faye testifies to the strength of the evidence brought forward by Dr. Draper. With the exception of Prof. John C. Draper, physicists, in so far as they have expressed their views, have generally accepted the hypothesis of Dr. Draper. No one, to our knowledge, has critically examined the hypothesis of bright lines in the solar spectrum.

The reader of Dr. H. Draper's account of his experiments will remember the difficulties he encountered in obtaining an air spectrum, of sufficient brightness to record itself upon the photographic plate. The time that has elapsed since his work does not seem to have made those difficulties less, and, in spite of all that our ingenuity has been able to devise, we have been practically confined to taking the spark in free air or oxygen at atmospheric pressure, notwithstanding the broad and hazy character of the lines under these conditions.

Not to record a long list of failures extending over several months, we will briefly describe the arrangements in their final form.

An alternating current dynamo driven at 2,000 revolutions per minute is connected to a commutator of four segments upon a fixed spindle, around which revolve two pairs of brushes. The result of this combination is that the current is very frequently and sharply interrupted. This interrupted current is used to excite three large quantity coils connected in series. From two to twelve jars were employed as a condenser to the secondary current. The spark was taken between two stout rods of aluminium placed immediately in front of the slit, and the spark passed between them with a deafening rattle, and gave about the light of two candles. We tried Dr. Draper's device of a soapstone compressor for the spark, but in our hands the walls of the soapstone near the spark melted down, and formed a conducting surface over which the current passed.

The photographic apparatus is the large instrument of Professor Rowland,—a concave grating with ruled surface 6×2 inches, mounted upon an iron girder 23 feet long, moving upon two tracks at right angles, as has been previously described by him and others. Sunlight is introduced by a heliostat with mirror silvered on first surface, and an image of the sun formed on the slit by means of a quartz lens of five feet focus. The method of working with the apparatus so arranged has been as follows.

The points of aluminium being permanently fixed in front of the slit, sunlight is introduced, the camera brought to focus once for all, and set to any required wave-length upon a convenient scale. The photographic plate is then placed in the camera, and a shutter immediately in front is set to expose the upper half of the plate. Exposure for the sun is then made; the sunlight is then cut out, and the shutter moved to cover that part of the plate already exposed, and the lower half exposed. The spark is then started and worked from 15 to 30 minutes. In addition to the spectrum of lines there is a considerable continuous spectrum, which after a time causes fogging of the plates; so there does not seem to be any gain in an exposure of more than half an hour. The feebleness of the air lines can be judged of when we state that, with the same plate, breadth of slit, etc., we get a metallic spectrum in the arc in ten seconds, strongly photographed. There was sufficient iron present in the electrodes as impurity to give the strongest iron lines feebly, and these have been of use in determining that no displacement had happened, although from the nature of the arrangements such disturbance could hardly occur.

On the negative produced as above indicated the two spectra lie exactly edge to edge, like a vernier and scale, and are in the best possible position for the accurate determination of the position of the air lines. The original plan contemplated a determination of wave-lengths of all the air lines throughout the entire spectrum; but persistently bad weather and other causes have compelled the postponement of the completion of this work, though we are now able to give it complete from wave-length 3740 to wave-length 5030.

The photographic map of the solar spectrum of Professor Rowland has made easy what would otherwise have been an undertaking of extreme labor and difficulty. The best of engraved maps of the violet region of the spectrum to beyond F are comparatively worthless. Even on the elaborate map of Vogel, the result of years of labor, it is difficult certainly to recognize other than the more prominent lines, and you never feel quite sure of your positions; but we turn to the map of Rowland with the certainty of finding every line in its true order and magnitude, so that what was formerly most difficult has now become very simple, and the position of any well-defined air or metallic line can be read directly, by comparison of the photograph with the map, to the tenth of a wave length.

We here give a table of wave-lengths as determined from our photograph of the sun and air spectra:—

3749·80	Strong, agrees.
3755·35	" "
3830·60	Faint and broad.
3839·275	Dim and broad.
3842·30	Very faint.
3843·00	"
3850·70	Faint.
3857·40	"
3863·80	"
3864·90	"
3882·45	Strong.
3893·50	Faint.
3894·95	"
3896·40	"
3896·90	"
3900·975	Sharp.
3902·20	Very faint.
3906·00	Sharp.
3912·30	Fairly strong.
3919·25	Strong, agrees.
3935·10	Very faint.
3936·90	Faint.
3938·80	"
3939·80	"
3940·70	"
3941·40	"
3942·48	Sharp.
3946·20	"
3948·10	Very faint.
3949·00	Sharp, may agree.
3951·45	"
3954·85	Strong.
3956·175	Strong, agrees.
3958·10	Faint.
3958·90	
3959·975	Sharp.
3963·70	"
3968·70	
3973·60	Strong.
3981·40	
3982·97	Faint.
3992·87	Sharp, agrees.
3995·10	Very strong.
3998·81	Very faint, may agree.
4008·39	
4011·34	Faint.
4035·34	Band.
4041·39	Band.
4066·84	Faint.
4070·24	Strong, may agree.
4072·34	"
4076·19	"
4078·83	Faint, agrees.
4085·24	
4085·84	
4088·64	Faint.
4093·09	"
4097·49	"
4105·04	Strong.
4105·21	"
4109·76	Very strong.
4111·01	Very faint.
4112·16	"
4119·36	Fairly strong.
4120·46	Faint.
4121·52	"
4121·56	"
4123·82	Agrees.
4132·82	Faint.
4133·79	"
4145·87	
4147·42	
4151·92	
4153·57	May agree.
4155·42	Faint.
4156·79	
4164·72	Faint.
4166·72	"
4169·47	Agrees.
4172·12	
4175·72	Band.
4177·92	Very faint.
4179·92	Faint band.
4185·32	Very strong.
4190·00	"
4193·77	Very faint.
4198·72	
4199·22	May agree.
4202·12	"
4205·72	Very faint.
4206·92	Band.
4209·12	Very faint.
4214·92	"
4223·17	Faint on band.
4224·92	" "
4225·92	" "
4228·52	Band.
4236·67	"
4241·92	
4249·02	
4253·42	Very faint.
4266·32	Faint.
4271·22	"
4274·82	Very faint.
4277·90	Faint.
4279·90	Fairly strong.
4282·40	Faint.
4291·90	"
4303·80	Very faint.
4305·67	"
4309·87	Faint and sharp.
4312·72	" "
4315·52	" "
4317·20	Strong.
4319·50	"
4322·80	Faint, may agree.
4323·90	Very faint.
4325·90	Agrees.
4327·60	Very faint.
4328·42	"
4330·37	"
4331·20	"
4332·40	Sharp.
4336·77	
4345·52	Strong.
4347·47	Faint.
4347·94	Strong.
4349·30	"
4351·40	"
4353·70	"
4356·62	Faint.
4362·90	
4365·40	Faint.
4366·92	Strong.
4369·60	Faint.
4371·40	"
4379·70	"
4381·50	"
4385·30	Very faint.
4385·40	"
4386·50	Nebulous.
4396·30	Faint.
4401·22	
4415·00	Strong, agrees.
4417·17	" "
4421·00	Faint.
4426·00	"
4430·04	"
4431·90	Very broad dim band.
4434·27	Sharp.
4439·47	Broad dim band.
4443·00	" "
4447·09	Very strong.
4452·40	Sharp.
4456·00	Faint and sharp.
4459·90	Faint.
4465·40	Sharp.
4466·00	"
4468·02	Very faint.
4469·50	"
4472·90	"
4477·87	Broad and faint.
4481·87	Sharp.
4487·94	
4489·90	Faint.
4496·97	Sharp.
4498·95	Faint.
4503·05	Fairly strong.
4507·72	"
4511·85	Sharp.
4520·50	Strong, may agree.
4544·50	Fairly strong.
4565·97	Sharp.
4572·02	Sharp, agrees.
4577·50	Sharp.
4578·55	"
4582·32	"

4583·15	Very strong.	4676·40	Faint, may agree.	4822·12	Faint.
4587·45	Sharp.	4681·10	Very faint.	4825·12	Faint, may agree.
4588·05	"	4682·40	"	4842·00	Faint but sharp.
4588·92	Very faint.	4687·15	"	4863·92	" "
4589·40	"	4688·80	"	4877·70	Faint.
4590·00	"	4691·40	"	4878·80	Very faint.
4590·95	Strong, may agree.	4694·15	Strong.	4879·90	"
4592·00		4695·15	Faint.	4891·27	"
4592·95	Strong.	4696·70	Very faint.	4894·90	"
4596·20	"	4699·40	Broad and faint.	4898·70	"
4601·37	Very strong.	4700·40	Faint.	4906·77	"
4607·20	"	4701·65	"	4907·67	"
4609.45	Sharp, may agree.	4703·02	Agrees.	4913·69	Sharp.
4612·75	Faint.	4705·42	Fairly strong.	4915·12	Sharp, but faint.
4614·05	Strong, agrees.	4710·20	"	4916·86	Sharp.
4621·42	Strong.	4712·87	Very faint.	4936·86	Band.
4630·73	Very strong.	4719·92	"	4940·85	Sharp.
4634·00	Sharp.	4731·27	"	4945·01	"
4638·90	Strong.	4733·95	"	4945·81	"
4640·75	Rather faint.	4740·20	"	4950·21	"
4641·90	Fairly strong.	4744·20	"	4951·41	Nebulous band.
4643·45	Strong.	4753·82	Sharp.	4953·85	Sharp, agrees.
4645·40	Faint.	4760·07	"	4955·16	
4649·25	Strong.	4763·82	"	4960·16	
4651·02	Fairly strong.	4771·82	"	4969·85	
4654·10	Faint.	4775·07	"	4972·85	
4654·85	"	4782·62	Very strong.	4979·90	
4655·90	Faint band.	4788·27	Very faint.	4983·06	Sharp, may agree.
4658·05	Very faint.	4791·32	Sharp, agrees.	4993·95	Faint.
4659·60	"	4798·97	Very faint.	4997·60	"
4665·70	Faint.	4800·82	"	4999·31	Agrees.
4667·55	"	4802·37	Very strong.	5001·55	Faint.
4671·65	"	4808·94	Very faint.	5011·06	Sharp, agrees.
4672·30	"	4810·02	Faint.	5012·50	Faint.
4673·30	Very faint.	4811·92	"	5018·55	May agree.
4674·95	Faint, may agree.	4813·52	"	5022·95	Faint, may agree.
		4816·60	Very strong.	5033·85	Very faint.
		4820·90	Faint.		

In regard to the accuracy that may be expected of the above positions, we feel sure that few of them are wrong by more than a tenth of a wave-length, and those are of the class "Very faint," or "Broad and nebulous." The better defined lines we believe to be correct to within less than the above amount. The method of comparison we have used admits of much greater accuracy than this, but the ill-defined character of the air lines puts a limit to their accurate placing. Compared with Thalen's positions, they should be credited with ten times the accuracy at least. Some of Thalen's bands are resolved into two or more in our instrument.

Prof. John C. Draper projected his spectra upon a scale of wave-lengths by means of a stereopticon,—a method which does not inspire confidence in his results, when we consider the distortion produced by projecting lenses.

The scientific world seems largely to have accepted the wave-lengths of Ångström and Thalen as final. One eminent au-

thority speaks of them as the "ne plus ultra" of spectroscopic accuracy; and any attempt to revise or correct them may be looked upon as presumptuous. However, we believe the time has arrived when the whole of Thalen's work on metallic spectra must be re-examined. It is safe to say that he has tabulated not more than one line in many metals where several exist, and his positions are occasionally wrong by as much as two wave-lengths.

As yet no approach to the accuracy with which the solar spectrum has been delineated has been attempted in metallic spectra,—a remarkable fact, when we consider that the chief interest that attaches to the study of the solar spectrum is in its connection with spectra of terrestrial elements.

The test of the existence of oxygen in the sun is the coincidence of the bright lines of the spectrum of oxygen with bright lines or with dark lines of the solar spectrum. If the bright lines of any metallic vapor formed in the electric arc or the electric spark coincide with the dark lines of the solar spectrum which is photographed directly above the spectrum of the metal on the same sensitive plate, the evidence is usually considered conclusive in regard to the existence of the metal in the sun. In the case of iron, where hundreds of lines of the metal coincide with the dark lines in the solar spectrum, not only in exact position but in general grouping and character, the evidence cannot be doubted by any one who has carefully examined it. When a majority of the lines of any metal coincide with dark lines in the solar spectrum under high dispersion, not only in position but in grouping, while a few of the metal lines have no representatives in the solar spectrum, there is a probability that the corresponding lines wanting in the sun have been obliterated by superposed lines or bands of other metals. In our paper "On the Existence of Carbon in the Sun," we have called attention to a case of such obliteration. It is probable, also, that the non-appearance of certain lines in the sun may be due to certain conditions of temperature. We have discussed this point more fully in the paper on carbon, above referred to.

The same remarks apply to the coincidence of the lines of any element with the supposed bright spaces in the sun. The value of the test of coincidence increases with the number of coincidences. If an element has only two or three lines, and these two or three agree in position with dark lines in the solar spectrum, the evidence of the existence of the element in the sun is not conclusive. It is supported, however, if there is any striking peculiarity in the lines of the element which is reproduced in the corresponding lines in the solar spectrum. Thus the nebulous character of the lines of magnesium is perfectly

reproduced in the corresponding lines in the solar spectrum. The test of coincidence, therefore, requires primarily a normal spectrum and the highest possible dispersion. The earlier observers were limited to the instruments of small dispersion, and the entire number of lines observed in the solar spectrum was small compared with that given by the best modern apparatus. The chances for an apparent coincidence were therefore much greater, and evidence of a very misleading character could be obtained.

In Dr. H. Draper's published photograph, the coincidence of the greater part of the oxygen lines with bright bands in the solar spectrum is striking; and it is not a matter of surprise that he was led to conclude the connection between the two spectra to be a physical one, and to announce the existence of oxygen in the sun as proved. Instances are not infrequent where instrumental imperfection or lack of power has led to results unsupported by later and more powerful research. Witness the spots of Venus of the older observers. Now when we apply to the spectra of the sun and oxygen a dispersion and definition that show the minute detail of each, the "bright bands" at once vanish, or no longer appear as such, and all the apparent connections between them and the oxygen lines disappears also. The bright bands of Dr. H. Draper's spectrum are found to be occupied by numerous dark lines, of various degrees of intensity; but the hypothesis of Prof. J. C. Draper, that these are the true representatives of the oxygen lines, is rendered untenable by the lack of any systematic connection between the two. It happens quite frequently that an oxygen line falls centrally upon the space between two dark lines of the solar spectrum, but not more frequently than we might expect as a matter of chance, when we consider the vast number of lines and spaces; and the fact that the spaces are no brighter than the surrounding background of the solar spectrum would not seem to permit of their interpretation as bright lines.

The subject of bright lines in the solar spectrum is one upon which men will probably differ, and we have sought information upon it. Of course there is no *a priori* reason why such bright lines should not exist, as they do in many stars; but we have photographed the sun's spectrum every day that the sun has shone for nearly five months, without finding a line that could with certainty be pronounced brighter than its neighbors; and it must be admitted that the photograph is the best of photometers in such a case.

In regard to the other three spectra of oxygen of Schuster we have nothing to say; but as far as concerns the spark spectrum in air and the solar spectrum from wave-lengths 3749·8 to 5033·85 we can safely affirm that there is no physical connection between them.

ART. XXX.—*Bismutosphærite from Willimantic and Portland, Conn.;* by H. L. WELLS.

THROUGH the kindness of Professor Brush I have been enabled to examine two specimens of basic bismuth carbonate which are of considerable interest, inasmuch as their composition appears to be identical with that of Weisbach's bismutosphærite.* Weisbach gave this name, upon reinvestigation, to Werner's "Arsenik-Wismuth," which, as he remarks, had been called "Luftsaures Wismuth" by Adolph Beyer, who died as early as 1805. The composition of bismutosphærite has been considered doubtful† because Winkler's analysis included no water and footed up only to 97·83 per cent, but Weisbach states distinctly that the mineral is anhydrous, and, since Winkler used only 330 milligrams of the material for his analysis, it is quite probable that his loss may have been due to other causes than the presence of water.

The specimen from Willimantic, which weighed about ¼ lb., was given to Professor Brush by H. N. Bill, Esq., of Willimantic, who has kindly furnished the following description of the locality. "The mineral occurs in small isolated masses embedded in albite with garnets. The vein of which it was a part was composed of large crystals of orthoclase, muscovite and occasional fine crystals of smoky quartz. The locality is on the Linen Co's property near the west end of mill No. 2. A considerable outcrop of gneiss originally existed at this point, but it has all been utilized in building the mill. It was during the blasting of this ledge that the vein was opened and the mineral discovered. The locality is now inaccessible, the blasted portion being covered by a fine grassy lawn, while the portion originally exposed in the bed of the river has been flooded by a pond."

The material of which the specimen is almost wholly composed has a dark gray color and gives a light gray streak. It shows evidences of a bent columnar structure, suggesting that it is a decomposition product of bismuthinite, and a small nucleus of bismuthinite, found in the interior of the specimen by Professor Brush, shows that this is the actual source of the mineral.‡ Its hardness is between that of calcite and that of fluorite (3·5). The specific gravity is 7·42 according to a determination made on a chemical balance with the precaution of removing air from the fragment used by placing it in boiling water before

* Jahrb. Berg-Hütten., 1877, p. 49.—Dana's Mineralogy, 5th edition, Appendix III, p. 15.

† A. H. Chester, this Journal, III, xxxiii, p. 291.

‡ Weisbach states (l. c.) that the original bismutosphærite often encloses a nucleus of metallic bismuth.

the weight in water was taken. Heated in the closed tube it gives off a minute quantity of water and melts readily. It dissolves in acids with effervescence; with HCl a small, flocculent, black residue is left in which bismuth and sulphur were detected; with HNO_3 it dissolves completely. Scattered through the gray material numerous minute shining scales are to be noticed, which are most numerous along the cracks or more easily separated surfaces. A small cavity in the specimen was lined with these scaly crystals. They have a white color with a brilliant luster. Their aspect is orthorhombic, but they are too small and thin for measurement. Qualitative tests showed that they are composed of an anhydrous bismuth carbonate, and it seems probable that their composition is identical with that of the massive material in which they occur, but, unfortunately, there was not enough of the crystals which could be separated from the gray material to afford material for a quantitative analysis.

On some parts of the specimen a yellowish-white coating is to be observed, which in places is made up of minute spherical nodules, the form on a small scale of the original bismutosphærite.* This is also apparently an anhydrous bismuth carbonate, but, like the scaly crystals, its quantity is too small for quantitative examination.

Mr. S. L. Penfield has kindly made an optical examination of the gray substance and reports as follows: "A thin section does not at first sight appear to be homogeneous, but shows under the microscope a dark ground-mass through which irregular patches of a pale yellowish-green color are scattered. The light patches are not perfectly transparent, but are translucent and have the appearance of a kaolinized feldspar. The material of the darker ground-mass is probably the same as that of the light, but stained and rendered practically opaque by fine particles of dust of some black material. If, as is probable, the mineral is a decomposition product, the black dust-like particles may be the last traces of the original mineral. Light streaks, which may be original cleavage directions along which decomposition has gone on more completely, indicate crystalline structure, while the lighter, translucent parts of the section polarize the light and show an extinction parallel to these directions."

A chemical examination gave much more satisfactory results in regard to the purity and homogeneity of the mineral than would have been expected from the results of Mr. Penfield's microscopic examination. The actual amount of the black material, probably bismuthinite in an extremely fine state of division, which had such a marked influence upon the transparency of the thin section, proved to be very small; moreover, a careful qualitative analysis showed that the only impurities besides the

* In this a size larger than that of a pea is mentioned by Weisbach.

bismuthinite are a trace of iron and in some parts a very small quantity of insoluble silicates. The remarkable uniformity in the composition of separate portions, as shown by the analyses which follow, is a strong argument in favor of homogeneity.

Mr. E. S. Sperry of this laboratory has made the following analyses of two separate portions.

	A.	B. I.	B. II.	B. III.
Bi_2O_3 by ignition,	92·07	92·05	92·04	92·07
CO_2	8·01	7·90	7·96	7·91
H_2O	0·90	0·48	0·66	0·49
	100·98	100·43	100·66	100·47
Bi_2O_3 by determination as BiOCl	----	----	----	91·09

The above analyses and those that follow were made by igniting the substance in a boat in a combustion-tube through which dry air was passed. More than 1 gram of substance was used for each analysis. The H_2O and CO_2 were collected and weighed as in organic analysis, while the residue in the boat gave the "Bi_2O_3 by ignition." In one case, B III, this residue was dissolved and BiOCl was weighed on a Gooch filter. In these analyses the small amount of Bi_2S_3 present was disregarded, but Mr. Sperry made a determination of the residue insoluble in dilute HCl by collecting it on a Gooch filter, drying at 100° and weighing. He found:

	B. IV.
Black residue	0·56 per cent.

Mr. Sperry's analyses showed such uniformity in the two portions examined that I was led to make a somewhat more detailed analysis of a third sample. My results were as follows:

	C. I.		Calculated for Bi_2CO_5
Bi_2O_3	91·64*	92·06 ignited residue.	91·41
SO_3	0·34		
Insoluble silicates	0·08		
Fe_2O_3	trace		
CO_2	8·03		8·59
H_2O	0·47		
	100·56		100·00
Deduct O,†	·28		
	100·28		

* By difference; i. e., the ignited residue minus the SO_3 and insoluble silicates.

† It is assumed that the SO_3 contained in the ignited residue resulted from the oxidation of Bi_2S_3; therefore 4 atoms of oxygen are deducted for each atom of sulphur.

	C. II.
Black residue insoluble in HCl,	0·49 per cent.
Deduct insoluble silicates,	0·08
Bi_2S_3 by difference,	0·41

The result obtained from the analysis of the Willimantic mineral led me to examine a specimen of bismuth carbonate in Professor Brush's collection from Pelton's quarry, Portland, Conn. This specimen has a greenish-yellow color, and gives reactions like the specimen from Willimantic, except that it does not leave a black residue when dissolved in HCl. It shows evidences of a bent columnar structure, but on a much smaller scale than the other specimen. Under the microscope it appears as a somewhat porous mass, made up almost wholly of an apparently homogeneous material of a yellowish green color with an oily luster, but with some streaks of different colored material varying from white to dark gray. A specific gravity determination gave the number 6·83, but this is of little value on account of the porosity of the mineral. Chemical analysis gave the following results:

Ignited residue,	91·82
CO_2	7·54
H_2O	0·94
	100·30

A determination of Bi_2O_3 in the "ignited residue" gave 89·03 per cent. The difference, amounting to 2·79 per cent, between the Bi_2O_3 determined and the "ignited residue" is probably to be accounted for by the presence of 0·49 per cent of insoluble silicates, and also a little CuO and a considerable amount of Fe_2O_3 which were not determined.

The analyses given in this article were all made on the air-dry material; drying, even in the desiccator, having been avoided from fear of removing water which belonged to the composition of the mineral. From the small amount of water found, since a part of it was probably hygroscopic moisture, and, since weighing water in a calcium chloride tube is apt to give slightly high results, these two specimens of bismuth carbonate must be regarded as virtually anhydrous; and, since the analyses agree quite closely with the composition corresponding to the formula $Bi_2O_3 . CO_2$, the existence of bismutosphærite must be considered as established, although the name is not appropriate to the external form of the specimens under consideration, unless, indeed, the slight coating on that from Willimantic shows on a small scale the form from which the mineral is named.

Sheffield Laboratory, May 18, 1887.

ART. XXXI.—*Note on some remarkable Crystals of Pyroxene from Orange County, N. Y.*; by GEORGE H. WILLIAMS.

CERTAIN yellowish gray crystals of pyroxene occurring in the crystalline limestone of Orange County, N. Y., have a very peculiar tabular habit produced by the unusual development of the basal pinacoid. Dr. Lewis Beck figures these crystals in his Mineralogy of New York,* although his drawing wrongly represents the basal plane in the position of the orthopinacoid, for which he evidently mistook it. Beck gives the locality for these crystals as two and a half miles north of Edenville. In 1860, Professor G. vom Rath described and figured some of the same crystals from the collection of Dr. Krantz in Bonn.† He gives the locality where they are found as Warwick, Orange County, N. Y., which is probably less accurate than that given by Beck. Vom Rath's first figure represents a crystal of the ordinary habit; tabular according to the base (c) and showing besides the forms: $\infty P \bar{\infty}$ (a), $\infty P \breve{\infty}$ (b), ∞P (m), P (s), 2P (o) and $-P$ (u). His second figure represents a twin crystal of a more prismatic habit, formed according to the common law for pyroxene. This shows, in addition to the above named planes, the form $P \bar{\infty}$ (p). Vom Rath further mentions the striation of these crystals parallel to their basal pinacoid, which he refers to an irregularity of growth, although he was the first subsequently to explain it as due to twinning.‡ He also says that they are externally changed by paramorphism to an aggregate of fine hornblende needles, which produces a lustrous shimmer on the surfaces.

Professor Des Cloizeaux also mentions and figures these crystals in the first volume of his "Mineralogy" published in 1862.§ His first figure is like vom Rath's and represents a similar simple crystal. His second shows a hemimorphic development in the direction of vertical axis, there being on one side of the prismatic zone the forms: 0P (p), P (s), 2P (o), $P \breve{\infty}$ (e), and $-2P2$ (μ); and on the other side: 0P (p), $-P$ (u) and $-\frac{3}{2}P3$ (α) No mention of twin crystals from this locality (given as Warwick) is made by Des Cloizeaux.

A remarkably fine group of these Orange County pyroxene crystals, which came into the possession of the Johns Hopkins University mineral cabinet with the purchase of the collection of the late E. W. Root of Clinton, N. Y., seems worthy of a brief notice on account of the singularity of their form. This

* Mineralogy of New York. Albany, 1842. 4°, p. 293, fig. 215.

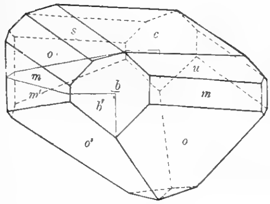
† Pogg. Ann., Bd. cxi, p. 263, taf. iii, figs. 5 and 6.

‡ Zeitschrift für Krystallographie, v, p. 495, 1881.

§ Manuel de Minéralogie, vol. i, p. 54, 1862. Atlas, figs. 57 and 58.

group consists of six simple crystals of the usual tabular habit and of two larger ones, which are at the same time twins and hemimorphic. The largest of these crystals measures $3\times3\frac{1}{2}^{cm}$, and is represented in figures 1 and 2. The upper portion

1.



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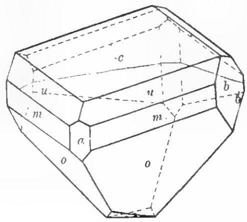

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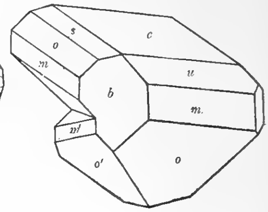


belongs to a single individual, having the usual habit and showing the usual forms: $0P$ (c), $-P$ (u), P (s), $2P$ (o), ∞P (m), $\infty P\grave{}\infty$ (b) and $\infty P\bar{\infty}$ (a). Below, however, toward the front, we have only the forms: $2P$ (o) and $P\bar{\infty}$ (p), indicating that the crystal is hemimorphic in the direction of the vertical axis, as first noticed by Des Cloizeaux.* The lower back quarter of the crystal is moreover exactly like the lower front quarter, but in a reversed position, so that the lower half of the individual is a twin as represented by vom Rath, while the upper half is apparently simple and of the usual habit! The boundary of the quarter in twinning position is represented in the figure by the light line.

The second, slightly smaller crystal ($2\times2\frac{1}{2}^{cm}$) is essentially the same as the one just described, though it shows the twinning structure even more plainly, as may be seen from figure 3.

In all of these crystals the superficial alteration to hornblende has progressed so far as to render the planes unfit for exact measurements. The angles were, however, determined by a contact goniometer with sufficient accuracy to identify the symbols above given. The striation parallel to the basal pinacoid, so common in all pyroxene crystals from the crystalline limestones of New York, is here very distinctly marked.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, Md., April, 1887.

* It is perhaps doubtful whether a crystal can properly be spoken of as hemimorphic in any direction except that of an axis of symmetry (cf. Groth), but this case is so analogous that it is difficult to describe it by any other term.

ART. XXXII.—*The Flow of Solids:* or Liquefaction by Pressure;* by WILLIAM HALLOCK.

THE question before us is this: Can solids be liquefied by pressure alone, without a rise of temperature? Also, is chemical action possible during this enforced liquid state? Applied to rocks and rock-making magmas it becomes a question of the first importance to geologists; as such it has been frequently discussed theoretically, but has seldom been experimentally investigated.

Walter Spring seems to be the pioneer in these tests, having published very many results during the past few years.† His memoirs† would seem to have proved beyond doubt that pressures under 7000 atmospheres will liquefy most solids,‡ and that it is only a question of slightly higher pressure to liquefy nearly all. He also finds that chemical action takes place under these circumstances,† at least where the volume of the product is less than that of the original materials. Unfortunately, or fortunately, our confidence in Mr. Spring's conclusions is seriously shaken by the criticisms of Ch. Friedel§ and Ed. Jannettaz,‖ who were not able to reproduce the results given. Henri Tresca¶ carried out many striking experiments upon the *flow* of solids, but did not touch the question of their liquefaction.

In order that I may not be misunderstood, I wish, as far as I am concerned, to give definite meanings to certain terms. Primarily I wish to distinguish sharply between causing a body to flow, and making it a true liquid. Any substance may flow when the forces acting to cause the molecules to change their relative positions is greater than that tending to hold them in their original positions; that is, greater than the rigidity of the substance. Two causes may then produce a flowing, an increase of the disturbing force, or a diminution of the resisting power, the rigidity of the material. Pressure may act as the first of these causes, and heat, the second.

* This is an abstract of a paper in the Bulletin of the Geological Survey, Chemical Division, for 1886–7, which is itself compiled from a report made September 9th, 1885, to the director, J. W. Powell, under whose direction I undertook this work, and by whose kind permission this abstract is published.

† W. Spring. Bull. de l'Acad. R. de Belg., II, xlix, 1880, and III, ix, 1885; and Bull. de la Soc. Chem. de Paris, xxxix, 1883. and xlvi, 1886.

‡ W. Spring. Bull. de l'Acad. roy. de Belg., II, xlix, 1880.

§ Ch. Friedel. Bull. de la Soc. Chem. de Paris, xxxix, 1883.

‖ Ed. Jannettaz. Bull. de la Soc. Chem. de Paris, xl, 1884. Bull. de la Soc. Mineral. de France, viii, 1885.

¶ Henri Tresca. Mem. de l'Inst. Savantes Etranges, xviii, 1868. Comptes Rendus, lxvi, 1868; lxviii, 1869.

Whether rupture or flow takes place in any given case, when the deforming overcomes the resisting force, depends upon the nature of the substance, its limiting conditions, and *the time allowed for the accomplishment of the motion.*

For convenience I would classify substances as: True solids, viscous solids, viscous liquids and true liquids. True solids retain their shape under ordinary circumstances indefinitely. Viscous solids gradually yield to gravity and flatten out. Viscous liquids "fill" their containing vessels only after a fraction of a second. True liquids fill their containing vessel practically immediately. Examples of each class are steel, lead or paraffine, tar and water, respectively. It goes without saying that we have no examples of *absolute* or *perfect* liquids or solids. Absolute rigidity is as unknown as absolute liquidity. If these ideas are correct true "liquefaction" is a diminution of the rigidity of a substance until its molecules change their relative positions as easily as in the "true liquid" above defined.

In order that a substance may undergo a change in its chemical or crystalline character, it would seem necessary that it should be in the condition, at least, of a viscous solid, in order that the molecules may rearrange themselves if there be any force urging them thereto. *A priori* it is inconceivable to me how or why pressure should impart this freedom to the molecules. With the exception of a few substances at isolated points, as water between 4° C. and ice at 0° C., an increase of liquidity, or a diminution of rigidity is simultaneous with an increase of volume, i. e., with the increase of the intermolecular distances, which is usually accomplished by heating the substance. *In general for one and the same substance over considerable ranges of condition, the rigidity diminishes as the intermolecular distances increase.* How can pressing the molecules nearer together be expected to give to them a property which always accompanies their separation?

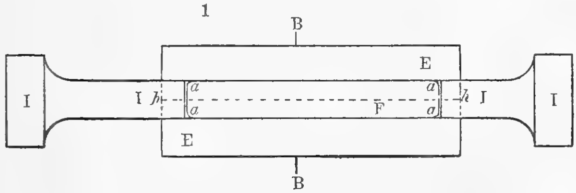
Apparatus.—Through the kindness of the Chief of Ordnance we were permitted to use in its leisure moments the beautiful testing machine built for that department by A. H. Emery,* and situated at the U. S. Arsenal, Watertown, Mass. I also gladly acknowledge my debt of gratitude for kindnesses and many good suggestions to Col. F. H. Parker and Capt. John Pitman of the Ordnance Corps, and to Mr. J. E. Howard, the engineer in charge of the machine.

Fig. 2 shows a vertical section across the holder on the plane B B of fig. 1, which gives a vertical section on A A of fig. 2. E E are the two halves in contact at *h h*, enclosing the cylindrical hole F, in which the substance to be pressed is placed.

* Report of the Board on Testing Iron, Steel and other Metals, vol. ii, 1881. Government Printing office.

h h are strips of tissue paper used as packing between the two halves. I I, fig. 1, are the two pins acting as pistons fitting into the hole F, transmitting the pressure. *a a* are copper "gas checks" placed in front of the pins to flare out and fill tightly the hole F, preventing any escape of material. Figs. 1 and 2 are $\frac{1}{5}$ natural size, the hole was 1 inch in diameter. Fig. 3 (scale $\frac{1}{10}$) shows the manner in which the apparatus was held in the testing machine, and the pressure applied. P and P are the jaws of the hydraulic clamps of the machine (capacity 1,000,000 lbs). H H blocks of steel. N also a steel block, holds the back (left hand, stationary) pin in place. V V is the clamp of the fixed end of the machine where the pressure is weighed. To apply the pressure the clamp P P is forced toward V V by a hydraulic piston, thus forcing the holder E E over the pin resting against O. In this manner a total compressive force of 1,000,000 lbs. is available, carefully and delicately weighed by the hydraulic balance of the machine. The pins yielded at 110,000 lbs. per square inch, hence in the experiments only 96,000 lbs. per square inch or 6,400 atmospheres was used.

1



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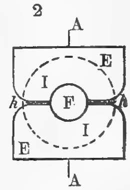

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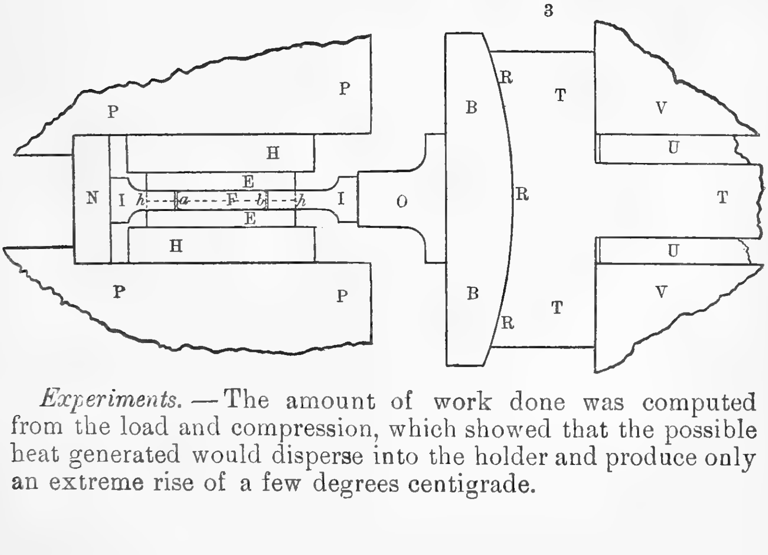
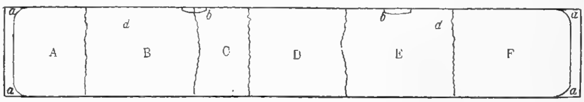


Experiments.—The amount of work done was computed from the load and compression, which showed that the possible heat generated would disperse into the holder and produce only an extreme rise of a few degrees centigrade.

"Granulated c. p. lead" in a paper roll was subjected to 6,000 atmospheres in the above apparatus. On taking it out there was not the least sign of fusion or true liquefaction. It was merely pressed together, and could easily be broken and reduced to the original grains between the thumb and finger. It is true these experiments were not performed *in vacuo*, a condition which Mr. Spring considers important. But if there is a true liquefaction, why does not the air rise to the top of the cavity and allow fusion as it does when the granulated lead is heated. There was no liquefaction—only a pressing or sticking together. Powdered bismuth behaved in precisely the same manner; also powdered calcite. As a critical experiment and a type of many others, the following may close those here enumerated.



The charge was composed as follows:

A, small section of antimony from a previous test.
B, piece of beeswax whittled round nearly filling the hole.
C, " " paraffine " " " " " "
D, ground bismuth in paper roll.
E, paraffine same as C.
F, small section of lead from a previous test.

d d, two double pointed tacks stuck radially into the wax and parafine; at *b b* two silver coins (old 3c. pieces) were laid on top of the wax and paraffine in the cylinder.

What is the condition of affairs to be expected after submitting this charge to 6,000 atmospheres? According to Mr. Spring's results we should expect the silver pieces and tacks to sink through the liquefied wax and paraffine, which would mix where in contact (B and C). Still more, the lead even would yield, then the antimony and bismuth, and these, by the action of gravity, would flow down and mix at the bottom of the cylinder while the wax and paraffine filled the top.

The actual result was that the substances *all came out just as they went in.* There was not the slightest trace of even a tendency to flow on the part of the metals. There was no sign of fusion between the wax and paraffine, which separated on their surface of contact (between B and C) clean and distinct. *d d* and *b b* did not sink to the bottom, but retained their original positions, the silver pieces were forced against the *top* of the cylinder so powerfully that their impression was left in the *steel* holder, easily seen and *felt*. The silver pieces were bent curved, fitting the inside of the cylinder. The wax and paraffine had yielded at first as viscous solids till they filled the cylinder, but under pressure developed a considerable rigidity.

It may be interesting here to quote some of Mr. Spring's results as obtained *in vacuo.**

Lead—Perfect fusion at 2,000 atm.; at 5,000 atm. it ran, as a liquid, out of all the cracks of the apparatus.

Bismuth—6,000 atm. perfect fusion.

Tin—4,000 atm. fusion.

Zinc—5,000 atm. perfect fusion.

Antimony—5,000 atm. beginning of fusion.

Sulphur prismatic—5,000 atm. fusion to the octahedral form.

" plastic—6,000 " ditto.

" octahedral—3,000 " ditto,

and so on through a long and varied list.

Conclusion.—At this stage of the investigation it may be premature to speak of conclusions, but I think there are here at least a few straws which suggest in which direction we are to look. To me it seems established that pressure alone cannot truly liquify a solid, i. e. diminish its rigidity, consequently we should scarcely expect chemical or mineralogical changes to be produced by pressure alone. Solids, and very rigid ones too, can be made to flow and act in that respect as viscous liquids by pressure alone, but it overcomes their rigidity without diminishing it.

Future investigation may contradict or modify this conclusion; at present I believe it the only logical one to be drawn from the facts at our disposal.†

ART. XXXIII.—*Analyses of some Natural Borates and Borosilicates;* by J. EDWARD WHITFIELD.

IN most of the published analyses of natural borates, boric acid has been determined either by difference or by some of the methods which have been shown to be inaccurate, and they are, therefore, subject to question as to the exact ratios and formulæ. A method for the direct estimation of boric acid‡ having been devised in this laboratory by Dr. F. A. Gooch it was thought advisable to repeat the analyses of a few of the borates and verify, if possible, the given formulæ or correct errors caused by defective analytical methods. With this object in view the following analyses were undertaken. The methods employed differ in many cases from those used by the analysts in the already published accounts of these minerals. In the estimation of the ferrous iron the method employed was to decompose the finely ground mineral with hydrofluoric and

* W. Spring. Bull. de l'Acad. R. de Belg., II, xlix, 1880.

† Since writing the above I have seen the article of E. H. Amagat [Comptes Rendus, July, 1887, this Journal, September, 1887] giving an account of his successful endeavors to do the opposite of what Mr. Spring did. He actually solidified liquid C_2Cl_4 by pressure alone.

‡ Am. Chem. Jour., ix, 23.

hydrochloric acids, in an atmosphere of carbonic acid, heating to a temperature of about 100° C. in a tightly sealed platinum vessel, devised and used expressly for such determinations. When the mineral was thoroughly decomposed, which is generally the case after standing twelve hours with occasional shaking, the solution was titrated with permanganate of potassium. This method is undoubtedly superior to that employed by Rammelsberg and Tschermak in their analyses. The direct estimation of the water was made, after drying the mineral at 104° C., with the apparatus devised by Dr. Gooch,* by which the errors caused by calculating the water from ignition and oxidation of the ferrous iron are eliminated. The silica in every case has been corrected by evaporation with hydrofluoric and sulphuric acids and the residue added to the precipitate of iron and alumina.

COLEMANITE, from Death Valley, California.—Of this mineral there were put at my disposal two specimens very different in appearance. One of them, designated as A, was a large, transparent crystal of the ordinary type, to all appearances perfectly clear and free from impurities.

By analysis the following results were obtained, and I insert for comparison the analysis by Mr. J. T. Evans† and the theoretical composition calculated from the formula given below:

	A.	J. T. Evans.	Theory.
H_2O	21·87	21·835	21·9
B_2O_3	50·70	50·990	50·9
CaO	27·31	27·175	27·2
MgO	·10	----	----
	99·98	100·000	100·0

The molecular ratios from analysis A are CaO : B_2O_3 : H_2O—2 : 3 : 5—resulting in the simple formula $2CaO . 3B_2O_3 . 5H_2O$, the calculated composition of which does not differ much from the results of the analysis. Mr. Evans calculated the same formula from his analysis in which the boric acid was determined by difference.

The second specimen, B, was from the same locality, but was in the form of a deposit implanted on gangue, and consisted of small blade-like crystals, almost white, but in some lights appearing of a greenish cast. Two analyses yielded the following result:

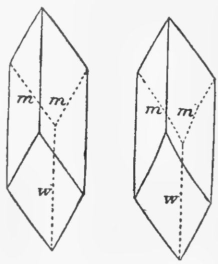
	B. 1.	B. 2.
H_2O	22·66	22·70
B_2O_3	49·56	49·62
CaO	27·36	27·40
MgO	·25	·26
SiO_2	·44	·47
	100·27	100·45

* Am. Chem. Jour., ii, 247, 1880.

† Proc. Cal. Acad. Sci., No. 1.

These results prove the mineral to be the same as variety A, but containing very slight impurities. The difference in general appearance of the two specimens suggested a crystallographic examination of variety B, and the following description has been furnished by Mr. H. S. Washington of New Haven.

"The white transparent crystals, of about 2 to 5^{mm} in length, occur implanted on a light porous gangue either in parallel position or in rosette-like aggregations, overlapping one another like shingles on a roof. They have in several places implanted on them small, white, opaque, spheroidal masses. The habit of the crystals is remarkable, being unlike almost all the forms of colemanite previously described. Prof. A. W. Jackson* gives one figure resembling these forms, though more complex. They look, at first sight, like acute rhombohedrons of calcite ; the combination of prism and orthodome giving the mineral a decidedly rhombohedral aspect, as is shown in the figure. None of the crystals examined admitted of good measurement, the faces being broken, rough, or curved. They were accurate enough however, for determining the symbols. The plane W was ($\bar{3}01$) curved very conspicuously and regularly, the face having near *a* (100) the position approximately represented by the symbol $\bar{5}01$. This habit was very constant, the prism *m*, (110) and orthodome W ($\bar{3}01$) being the only planes observed, with the exception of *b* (010) produced by the perfect cleavage, and a small and very uncertain plane observed in one or two cases replacing the edge between W ($\bar{3}01$) and *m'* ($\bar{1}10$)."



PRICEITE from Curry Co., Oregon.—The specimen examined was white and chalky, and proved to be very pure material; an analysis gave the following composition, and I copy the results of an analysis by Silliman† and another by Mr. Thomas Price‡ for comparison.

		Silliman.	Price.
H_2O	19·42	18·29	22·75
B_2O_3	48·44	[49·00]	[47·04]
CaO	32·15	31·83	29·96
NaCl, Fe_2O_3, Al_2O_3		·96	·25
	100·01	100.08	100·00

The ratios from my figures are CaO : B_2O_3 : H_2O—19 : 23 : 36, which do not conform to any simple formula. In both the earlier analyses the boric acid was determined by difference and there is a discrepancy between them of about 2 per cent.

* Bull. Cal. Acad., No. 4.

† Am. Jour. Sci., III, vi, 128.

‡ Am. Jour. Sci., v, 287.

Pandermite, from the island Panderma in the Black Sea.—The material was hard and compact somewhat resembling marble

H_2O	19·40
B_2O_3	48·63
CaO	32·16
	100·19

From these figures it will be seen that the priceite and pandermite are, in composition, identical, the difference being wholly in the physical appearance of the material, priceite is soft and friable while the pandermite is compact. From the results obtained there is no doubt but that they are the same mineral.*

Ulexite from Rhode's Marsh, Esmeralda Co., Nevada.—The material for analysis was taken from one of the nodules found in this locality, which on being broken exposed the fine, silky fibers characteristic of the mineral. An analysis gave the following figures.

		Calculated composition.
SiO_2	0·04	
Cl	2·38	
B_2O_3	43·20	45·34
SO_3	0.28	
CaO	14·52	15·04
Na_2O	10·20	8·83
K_2O	0·44	
H_2O	29·46	30·79
	100·52	100·00
Deduct O for Cl	·53	
	99·99	

The molecular ratios from these figures are $Na_2O:CaO:B_2O_3:H_2O$—16 : 26 : 62 : 163, which conform to no simple formula. If, however, we correct the analysis for impurities by throwing out the SiO_2, the K_2O as KCl, the remaining Cl as NaCl and the SO_3 as gypsum ($CaSO_4 . 2H_2O$) we can calculate the composition given above, from which we deduce the formula $NaCaB_5O_9 . 6H_2O$, which lies between the two formulas given by Rammelsberg.†

Ludwigite, from Morawitza, Banat, Hungary.—The material consisted of fine, radiating, silky fiber, almost perfectly black, but showing a tinge of violet when freshly broken, very tough when hammered, but easily cut, associated with quite pure magnetite. Analysis gave:

* Dana's Syst. Min., App. III, 97.

† Pogg. Ann., xcvii, 301.

B_2O_3	12·04
Fe_2O_3	37·93
FeO	15·78
MgO	30·57
MnO	0·16
H_2O	3·62
	100·10

The ratios are $B_2O_3 : Fe_2O_3 : FeO : MgO : H_2O - 17 : 24 : 24 : 76 : 20$; taking all the protoxides together with the water as basic, we have $B_2O_3 : Fe_2O_3 : RO - 3 : 4 : 20$. G. Tschermak* obtained for boric acid, by Marignac's and by Stromeyer's method, 16·09 per cent and 15·06 per cent respectively, but gives no water, and from his results deduces the formula $3MgO . B_2O_3 + FeO . Fe_2O_3$. If he sought for water by ignition, the oxidation of ferrous iron might easily have led to error.

Datolite.—The material investigated was the well known mineral from Bergen Hill, N. J., and consisted of crystals about 5^{mm} in diameter, translucent, white or of a pale greenish color. I have been unable to find any published analysis of the mineral from this locality, although it has been known for so long a time. By analysis I obtained:

SiO_2	35·74
FeO	·31
CaO	35·14
B_2O_3	22·60
H_2O	6·14
	99·93

The small amount of iron is undoubtedly present as an impurity; leaving this out, the molecular ratios are $SiO_2 : CaO : B_2O_3 : H_2O - 60 : 63 : 32 : 34$, giving the formula $B_2O_3 . H_2O . 2CaO . 2SiO_2$, or $H . CaSiO_3 . BO_2$.

Danburite, from Russell, St. Lawrence Co., N. Y.—This mineral has been fully described by Professors Brush and Dana,† although from the description given by them of the color of their specimen, I imagine they had material differing somewhat from mine. The mineral analyzed was reddish yellow to pink in color, brilliant in luster and associated with pyroxene, quartz and calcite. In the analysis referred to‡ the boric acid was determined by Stromeyer's method. The figures obtained by my analysis are given in the first column, the second is the analysis made by Mr. W. J. Comstock for Professor Brush.

* Tsch. Min. Mitth., 1874, p. 59.

† Amer. Jour. Sci., III, xx, 111, 1880.

‡ Loc. cit.

	1.	2.
SiO_2	49·70	48·23
B_2O_3	25·80	26·93
CaO	23·26	23·24
$Fe_2O_3+Al_2O_3$	1·02	·47
Ign.	·20	·63
	99·98	99·50

The comparison of the two analyses shows the material difference to be in the amount of impurities.

AXINITE.—Two specimens of this mineral from different localities were analyzed. The first, from Cornwall, England, was of selected crystals of a dark, clove brown color, translucent and implanted on quartz. The second was the axinite from Bourg d'Oisans, Dauphiny, France. This specimen was of a beautiful pearl-gray color, and in some of the smaller crystals almost colorless and quite transparent. The third analysis in the series is one of the Dauphiny axinite by Rammelsberg, and is copied from his description of the mineral* for comparison.

	1. Cornwall.	2. Bourg d'Oisans.	3. Bourg d'Oisans. Rammelsberg.
SiO_2	42·10	41·53	43·46
Al_2O_3	17·40	17·90	16·33
Fe_2O_3	3·06	3·90	2·80
FeO	5·84	4·02	6·78
CaO	20·53	21·66	20·19
MnO	4·63	3·79	2·62
MgO	0·66	0·74	1·73
K_2O	---	---	·11
B_2O_3	4·64	4·62	5·61
H_2O	1·80	2·16	1·45
	100·66	100·32	101·08

The ratios from the results of analysis No. 2 are: $SiO_2 : Al_2O_3 + Fe_2O_3 : \underset{11}{(FeO+MnO)} + \underset{40}{(CaO+MgO)} : B_2O_3 : H_2O$—$69 : 20 : 51 : 6 : 12$—or $10 : 3 : 8 : 1 : 2$—giving $B_2O_3 \,.\, 3R_2'''O_3 \,.\, 8R''O \,.\, 2H_2O \,.\, 10SiO_2$, or $BR_3'''R_4''H_2(SiO_4)_5O$. This expression will allow of the graphic formula:

$$\left.\begin{array}{ll} & \diagup SiO_4\equiv \\ Al & — SiO_4\equiv \\ & \diagdown SiO_4\equiv \\ Al & \diagup SiO_4\equiv \\ & \diagdown SiO_4\equiv \end{array}\right\}\begin{array}{l} Al \\ H_2 \\ BO \\ R_4'' \end{array}$$

Which gives for the calculated composition considering all the R'' as calcium:

* Zeitschr. d. Geol. Gesellsch., xxi, 689.

Al_2O_3	20·9
SiO_2	41·1
H_2O	2·5
CaO	30·7
B_2O_3	4·8
	100·0

While these results differ from those deduced by Rammelsberg from his formula, they agree very well with all the results of analysis No. 2.

Although the Stromeyer and Marignac methods of estimating boric acid have been shown to be unreliable, and the determination of any constituent of a mineral by difference is unsatisfactory, nevertheless it will be seen, on comparing the results of the various analyses, that the directly determined percentages of boric acid do not differ greatly from the older values.

I have to express my sincere thanks to Professor F. W. Clarke, by whose kindness the material for these analyses was put at my disposal, and also to Mr. Washington for kindly furnishing the description of the colemanite.

Laboratory of U. S. Geological Survey,
Washington, D. C., June 8, 1887.

ART. XXXIV.—*The Texas Section of the American Cretaceous;* by ROBERT T. HILL.

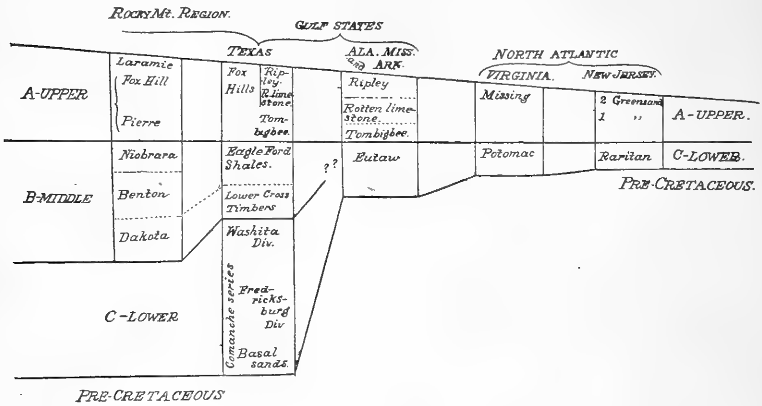
[Published by permission of the Director of the U. S. Geological Survey.]

IT is necessary to make a brief preliminary explanation of the Cretaceous of the United States as it is generally understood through accepted publications. There are at least five widely separated areas where the system has been independently studied by different authors, but little or no work has been done to trace the direct stratigraphic relations between them. In each of these areas, except the Californian which will not be touched in this paper, the North Atlantic (including New Jersey, Maryland, District of Columbia, Virginia and the Carolinas), the Gulf (including Alabama, Georgia, Mississippi, Tennessee, Arkansas and eastern third of Texas), the Rocky Mountain (including the Trans-Pecos and lower Rio Grande region of Texas), the principal subdivisions recognized are those of the following table.*

There is evident from a careful study of the faunas and stratigraphy of these regions, throughout them all, within the

* In the following diagram the solid lines represent complete faunal breaks, and the dotted lines indicate subdivisions whose species range into the including formations.

limits which I have marked, a great similarity of molluscan fauna, both specifically and generically, although the lithologic and stratigraphic characters vary in each. To the local formations of this collection of strata many different names have been given, and nearly every horizon has been termed a "group" regardless of any specific definition of that word, which has been used with a indefinite meaning in all the nomenclature of



the American Cretaceous. Instead of indicating a plurality of related phenomena, it has usually been applied indiscriminately to single characteristics based upon lithologic or specific culminations. For instance, in the Alabama regions the "Tombigbee sands," the "Rotten limestone," and the Ripley beds have each been called "Groups," when in reality together they constitute but a single group, as interpreted by the present accepted meaning of that word, their lithologic features being the fluctuations of an unbroken sedimentation, and the molluscan fauna continuous or interwoven by connective species from top to bottom. The "groups" so-called are really "horizons," representing the culmination of species or sedimental variations. The same can probably be said of the New Jersey Cretaceous above the Raritan clays, and the Fox hills and Pierre "Groups of the Northwest." The entire collection of strata of this upper portion of the American Cretaceous together constitutes a group which has been correlated with the Upper Cretaceous of Europe, but until our stratigraphic studies are completed, can only be called the "Upper Cretaceous."

In the Rocky Mountain and Texas regions other marine formations exist, but they have not as yet been traced east of central Texas. These include the Benton, Niobrara and Dakota sandstone groups of Meek and Hayden, which the former geologists correlated, upon good reasons, with the Lower Chalk or Upper Greensand of Europe. The state of knowledge

concerning the American Cretaceous does not justify any more specific term to these as a whole than "The Middle Cretaceous."

In all four of the regions above mentioned the undoubted open sea or marine groups rest upon the problematical formations of more shallow sediments, consisting of clays and sands, unaccompanied by any distinctive molluscan faunas, but a great abundance of vegetal remains: such as the Dakota sandstone in the Rocky Mountain region, the Eutaw clays in the Alabama region, the Potomac beds in the Virginias, and the Raritan clays, in New Jersey the relation of which to each other has not been published and is still a fertile question for investigation.*

The Dakota sandstone was erroneously thought, by Mr. Meek, to be identical with the Raritan clays of New Jersey, and Professor E. D. Cope has suggested that the Lower Cross Timber or Dakota Group of Texas was equivalent to the Eutaw Group of Mississippi. These as well as the Potomac formation of Rogers in the Virginias, and the Raritan clays of New Jersey, have been placed separately by many writers at the base of the Cretaceous series. If the Lower Cross Timber sands be of the age of the Dakota sandstone, as has been asserted by Shumard and others, and since when present they rest directly on top of this division, then we have in Texas not only the whole section of previous writers often visible in connected exposure, but a new and lower group of the marine Cretaceous beneath the hitherto recognized groups.

In this Journal of January, 1887, I first called attention to the fact that the current ideas of the relations of the Cretaceous strata of Texas were erroneous. In a paper read before the Philosophical Society of Washington,† January 29, 1887, I published a local section, typical of the whole region, including the strata from the Tertiary to the Carboniferous, and a condensed summary of the paleontology, stratigraphy and literature of the Cretaceous strata of Texas. I demonstrated the transitional position these strata occupied between the Atlantic States bordering upon the Gulf of Mexico and those of the Rocky Mountain region, and showed the existence there of a deep marine group of the Cretaceous which is older than any hitherto recognized on this continent. In a paper read before the Philadelphia Academy of Science, February 5, 1887, Dr. C. A. White published a résumé of the section furnished him by me for that purpose together with some brief deductions thereon and some correlations of his own. In the present

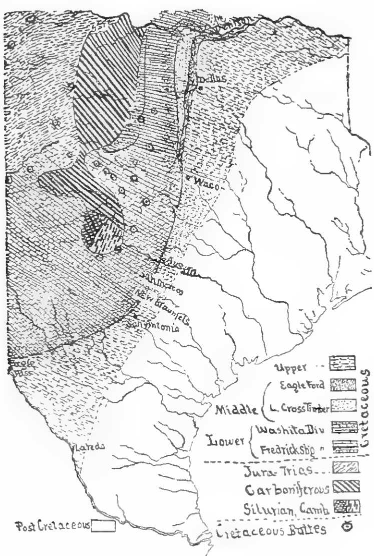
* Some important unpublished observations, which the writer does not feel authorized to use, have been made of late in these basal groups by McGee, Fontaine, Smith, Johnson and others.

† "The Topography and Geology of the Cross Timbers and Surrounding Regions of Northern Texas." See this Journal, April, 1887.

paper, to which the former was but introductory, I propose to diagnose more clearly this lower group and to explain many new features of it which throw much light upon the American Cretaceous section.

The strata of the Cretaceous period in the Texas region are so uniform and simple in their deposition, and the exposures and contacts of the groups so well marked, that they would be easily described, had not the publications by early writers * involved it in much confusion.

In the paper upon the Topography and Geology of the Cross Timbers, I showed how the westward extension of the upper Cretaceous from the other Gulf States abruptly ended along a line commencing in the vicinity of old Fort Washita, Indian Territory, and how it extended, as shown upon the accompanying map, from that point a little west of the cities of Denison, Sherman, McKinney, Dallas, Waco and San Antonio, and through the cities of Austin, San Marcos and New Braunfels, to a point eighteen miles west of Eagle Pass where it crossed the Rio Grande into Mexico. In addition to being the line of demarcation between the upper, the middle and lower groups of the Cretaceous formation, it is the western limit of the fertile Black Prairie Region, and separates the reliable agricultural from the grazing region of Texas; a complete change in the topography, meteorology and other natural conditions taking place when the line is crossed into the central denuded region. Geologically it is one of the clearest and sharpest lines of demarcation in America, and along it is to be seen what I believe the most comprehensive section of the Cretaceous formation to be found on this continent.



The Austin New Braunfels Non-conformity.

I have previously shown that along the northern third of this boundary line the country was generally level, with a uni-

* The writer has made a careful compilation of the literature of the geology of Texas, and endeavored to make a complete reference book for those who wish to trace the development of geological knowledge in that region. See Bulletin No. 45, U. S. Geological Survey. (In press.)

form, slope of surface to the southeast, that the underlying strata dipped in the same direction at a slightly greater angle; and that the escarpment lines, originally light or obscure, which mark the eastward recession of the rapidly disappearing formation, faced to the westward. Farther southward the topographic features along each side the line are less easily distinguishable, as in the vicinity of Waco, McLennan County, and Salado, Bell County. South of the last named place, however, they again become sharp, but the escarpment line increases in prominence, and instead of facing westward faces to the east, so that extending from Georgetown, Williamson County, to far southwest of San Antonio, there is an abrupt step of several hundred feet, the general altitude of the country above sea level diminishing from twelve hundred feet to five hundred within a score of miles. This escarpment passes near the cities of Austin, San Marcos, New Braunfels, the Post Office of Heliotes, eighteen miles west of San Antonio, and from thence westward to Rio Grande. It has long been known as a geographic feature of the country. It was first described by Kennedy, and later more in detail by Roemer, whose labors in Texas were mostly in its vicinity, and who placed it on his map of Texas. The latter utterly misinterpreted its geological features however as will be shown later on. When viewed from the International and Great Northern railroad, which runs from Austin to San Antonio, east of and parallel to it, the scarp has an irregular and varying appearance, resembling a broken range of distant hills. East of and at the base of the scarp is a gentle undulating plane, averaging twenty miles in width south of the Brazos, and extending the entire length of the State, which I have described previously as the Black Prairie region.* The plateau surmounting the escarpment and extending for hundreds of miles to the westward, is an entirely different country. Instead of the gentle undulations of the Black Prairie, the topography, where other than level prairie, has the more sharply defined features of buttes and mesas; and instead of the wide flood plains and low banks there are steep banks and sometimes rugged cañons. The color of the soil and underlying rock, it is true, approximates that of the Black Prairie, but in composition, structure and geological age they are entirely different, facts which have been overlooked by most writers.

A careful study of this escarpment line and the stratigraphy of the adjacent formations reveals some most interesting results. The underlying structure of the Black Prairie region, as seen all along the foot of the escarpment, which is the same as at Dallas, consists of massive, soft, chalky limestones (*A*),

* This is the "gently undulating, or hilly region" of Roemer, and the "soft lime rock region" of Roberts.

locally called "White Rock," or "rotten limestone." It dips at a visible angle to the eastward, disappearing beneath the Marine Eocene about twenty-five miles east of the escarpment line. Along the east bank of Shoal Creek, in the western part of the city of Austin, and in the banks of two unnamed creeks, emptying into the south side of the Colorado, opposite Shoal Creek, these limestones are seen to abruptly terminate, and in several places to rest usually upon blue calcareous shales (*B*), containing an entirely different fauna. These shales, which are only visible when protected by the above-mentioned limestones, owing to rapid disintegration, in turn are seen to rest upon the hard, eroded surface of another limestone formation (*C*) which composes the beds of the creeks, and, dipping from the northwest at an angle of fully fifteen degrees, also forms the whole face of the escarpment and plateau. In places the soft, rotten limestone of the Black Prairie is seen to rest directly upon the disturbed harder limestone without intervention of the shales. The characteristic strata and fauna of the first-mentioned formation invariably terminates at the foot of this escarpment, so that it is not found west of these contacts, nor that of the harder limestones of the escarpment and plateau east of them, as shown in the following diagram:

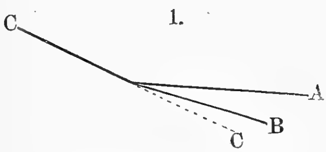


FIG. 1.—THE AUSTIN NEW-BRAUNFELS NON-CONFORMITY AS IT IS.—Contact seen on both sides of the Colorado River at Austin. *A*, Rotten limestone of Black Prairie region; *B*, shales; *C*, Lower Cretaceous limestone of escarpment and plateau.

There is a clear non-conformity between each of these divisions at Austin, both stratigraphically and faunally, not a single species extending from one division to the other, and the well-marked lithologic features of each terminating very abruptly. This non-conformity is clearly and unmistakably visible in and near Austin, San Marcos, Heliotes and New Braunfels; and this relation of the strata, which is the same along the face of the escarpment from Austin to Rio Grande, is diametrically opposite to that originally announced by Roemer (and accepted by Shumard and other writers down to the present day),* who made the Cretaceous of the plain at the

* But one author has ever published an opposite view to this relation of the strata. Professor E. D. Cope, in Bulletin No. 17 of the U. S. National Museum, makes the following statement, which, excepting its correlations, is true, but has apparently passed unnoticed. He says:

"An abrupt elevation commences somewhere to the southwest of Fort Worth and continues southward and westward, passing close to Austin, the State capital, and within twenty miles of the city of San Antonio, extending westward to the Rio Grande. The position of the limestone thus elevated is said to be older than that which occupies the adjoining lowlands, being correlated by some geolo-

foot of the highlands (*A*) older than that of the plateau, and to extend under it as shown in the following diagram. This error, which was the fundamental cause of the confusion of knowledge concerning the Texas cretaceous formation, has existed since Roemer's time.*

2.

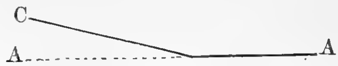


FIG. 2.—THE AUSTIN NEW-BRAUNFELS NON-CONFORMITY, as Roemer thought it. *A*, Rotten limestone of Black Prairie Region ("Kreidebildungen am Fusse des Hochlands," Roemer), supposed by Roemer to extend under the escarpment. *C*, Lower Cretaceous of escarpment and plateau, supposed by Roemer to rest on *A*.

Upon investigation of the three divisions of strata along the Austin New Braunfels non-conformity, the rotten limestone group of the Black Prairie Region at its foot, the harder chalky limestones of the scarp and plateau, and the intervening shales exposed along their contact, the following facts are apparent.

The Upper Division of the Texas Cretaceous.

The Rotten limestone† underlying the Black Prairie is a deep marine formation of much uniformity. Its strata are of great thickness and constitute a well-defined group. They are over 1500 feet at Spofford's Junction, as determined by artesian borings, and over a thousand in the Dallas and Austin regions.

The limestone of this upper formation, and its included yellow marls, extend into Arkansas and Mississippi on the north and Mexico on the south. The lower portion is composed of uniform sediments of deep marine origin, containing few molluscan remains, except giant Inocerami and a small Gryphæa-like Ostrea, found also in the Fox Hills and Pierre of Meek and Hayden, and Tombigbee sands and Rotten limestone of Hilgard, the exceedingly numerous varieties of which have been described under at least a dozen names‡ in different reports.

gist with the No. 2 of Meek and Hayden, while the lower part of the formation is said to represent No. 3. Without criticising their determination it may be observed that the fault which should exist has been observed at various lines along the elevation. I found it crossing the Heliotes Creek, eighteen miles west of San Antonio, at a locality pointed out to me by Mr. Gabriel W. Marnoch."

* Roemer confessed (see "Texas,") that he had not seen this contact, and that his conclusions, here shown to be erroneous, were based upon hypotheses. This was the fundamental and radical error in his otherwise excellent work.

† Roemer did not separate these limestones from the underlying shales, but described them together as the Cretaceous at the foot of the highlands, and erroneously thought, as shown on a previous page, that they extended under instead of resting unconformably upon the limestones of the escarpment. Shumard failed to detect Roemer's error, and fell into the same mistake. The two are easily separated in Roemer's writings by interpreting his careful descriptions of the strata and fauna of the waterfall and the ford near New Braunfels.—Kreidebildungen von Texas, p. 11.

‡ *Gryphæa Aucella* (Lamck.) Roemer; *G. vesicularis* Roemer (not Lamck.); *G. Pitcheri* Hilgard, not Mort.; *Ostrea patinia* M. and H.; *G. mutabilis* Con.; *O. Anomioformis* Hilg., not Roemer, most of which and many more varieties inseparably occur in the same localities.

The strata of the upper half become thinner and thinner and the fauna assumes a more littoral aspect toward the top, as in the Ripley beds of Tippah Co., Miss., the Navarro beds of Texas and the Fox Hills of Meek and Hayden. Along the lower Rio Grande the strata meet, and are either covered by or become identical with other strata having the lithologic and faunal characteristics of Meek and Hayden's No. 4 and 5, and which are the direct geographic continuation along the face of the Rocky Mountain axes of the same formation as exposed in New Mexico and Colorado.

Concerning this and all the following groups it is but proper to remark that the paleontology of Texas is of an unsatisfactory nature, and that none of it has been done or revised in accordance with modern biologic methods. Dr. Roemer's paleontologic descriptions are models of descriptive excellence, and it is easy to trace whatever element of error may occur in them, but the writings of most other writers have been fragmentary and unsatisfactory, being unaccompanied by any definite horizon or locality. Many of the fossils from Texas described by men who have never visited the State, convey no idea of their geological horizon, and several of the most common forms have been confusingly re-described. Most of the names given were in the days when species-making was looked upon as the chief accomplishment of the paleontologists, and resemblances were oftentimes intentionally ignored in order to add new names to the category. It was in this manner that many of the fossils from Texas have been twice, sometimes thrice, described under different names by separate authors. The latest descriptions of Texas Cretaceous fossils describes three alleged new genera, one of which had been described over a year ago under another name.*

With the assistance of the author's description, verified by years of personal investigation, I have recognized the following fossils† belonging to this upper grand division of the Cretaceous in Texas.

Nodosaria texana Con.	*Exogyra fragosa* Con.
Terebratula guadalupæ Roem.	*Exogyra læviuscula* Roem.
Hemiaster (*Cassidulus*) *parastatus* Mort., Desor.	*Exogyra subspatulata* Roem., Con.
Hemiaster texanus Roem.	*Gryphæa aucella* Roem.
Exogyra costata Say.	*Ostrea Lyonsii* Shum.
Exogyra costata, var. *ponderosa* Roem.	*Ostrea Owenana* Shum.
	Ostrea planatovata Shum.

* See Proc. Philad. Acad. Nat. Sci., Feb., 1887.

† These lists are not the result of guess-work, but of the most careful stratigraphic observations and compilation. It has been my endeavor for years to learn the exact stratigraphic horizon and range of the numerous fossils described from Texas, few of which were accompanied by any stratigraphic data.

Ostrea bellaplicata Shum.
Ostrea Blackii White.
Spondylus guadalupæ Roem.
Lima crenulicosta Roem.
Pecten burlingtonensis Shum.
Pecten Nilssoni Goldf., Roem.
Pecten simplicus Shum.
Pecten virgatus Nills, Roem.
Arca vulgaris.
Arca sublongata Con.
Trigonia thoracia Mort.
Cardita eminula Con.
Lucina parvalineata Shum.
Cardium congestum Con.
Cardium choctawense Shum.
Liopistha elegantula Roem.
Pachycardium Spillmani.
Cytherea.
Linearia cancellato-sculpta Roem.
Mactra texana Con.
Mactra alta M. and H.
Mytilus semiplicatus Roem.
Anatina sulcatina Shum.
Panopæa subplicata Shum.
Pholadomya Lincecumi Shum.
Pholadomya tippana.
Inoceramus Mort.
Inoceramus confertim-annulatus Roem.
Inoceramus crispii Mant.
Inoceramus crispii Mant.; var. *sulcatina* Whitfield.
Inoceramus striatus Mant., R'm.
Inoceramus biformis.
Avicula planiuscula Roem.
Legumen elliptica.
Siliquaria biplicata.
Radiolites austinensis Roem.
* *Cylichna secalina* Shum.
* *Cylichna striatella* Shum.
Anisomyon Haydeni Shum.
Turritella corsicana Shum.
Turritella irrorata Con.
Turritella Winchelli Shum.
Eulima ? texana Roem.
Scala bicarinifera Shum.
Scalaria Forsheyi Shum.
Chemnitza ? texana Roem.
Ficus subdensatus.
Pleurotoma ripleyana.
Pyrula, sp. ind.
Rapa supraplicata.
Purpurea cancellaria.
Solidula Riddelli Shum.
Strombus densatus.
Chemnitza gloriosa Roem.
Volutithes? navarroensis Shum.
Rostellites texanus Con.
* *Ringicula pulchella* Shum.
Nautilus elegans Sow., Roem.
Nautilus Dekayi.
Baculites anceps Lamck.
Baculites annulatus Con.
Baculites asper Mort., Roem.
Baculites spillmani.
Baculites tippaensis.
Turrilites splendidus Shum.
Turrilites helicinus Shum.
Scaphites verrucosus Shum.
Helicoceras navarroensis Shum.
* *Ptychoceras texanus* Shum.
* *Ammonites dentato-carinatus* Roem.
Ammonites flaccidicosta Roem.
Ammonites guadalupæ Roem.
Ammonites pleurisepta Con.
* *Ammonites texana ?* Roem.

* Fossils marked thus are doubtfully placed here.

A careful comparison of the above list, which is mostly in the nomenclature of the original descriptions, with similar lists published by different authors from New Jersey, Alabama and Mississippi, and the Rocky Mountain region, shows that nearly a third of the forms can be reduced to synonyms and that fully three-fourths of the species are common to the Upper Cretaceous of these regions, and that the faunal cessation at its base is as clearly marked. The writer does not believe in general correlations, but Mr. Meek has clearly shown the con-

tinuity of this fauna from New Jersey to the Rocky Mountain region; and I believe that both faunally and stratigraphically, this Cretaceous, at the foot of the highlands, is the direct geographic and geologic continuation of the Upper Cretaceous of the United States in general, and of the Gulf States region in particular, including the so-called "Rotten limestone," "Ripley," and Tombigbee Sand groups of Hilgard and the "Fox Hill," the Fort Pierre, and perhaps the upper Fort Benton groups of Meek and Hayden. This group of strata taken as a whole, from New Jersey to British Columbia, is the upper division of the American Cretaceous, and, as has been so frequently expressed by Vanuxem, Lyell, Pictet, Meek, and others, is the representative of the Upper or White Chalk of Europe.

Middle Division of the Texas Cretaceous.

The middle division of this Austin section (B) consists of argillaceous shales and a few thin bands of limestones and is but a fragment of the same formation more fully developed northward. Careful investigations have not been made to show the conformity with the overlying group, but faunally and lithologically there is no transition between them in the Austin region. Dr. B. F. Shumard, without having recognized their identity, gave these shales two positions in the composite section† which he made up of his brother's, Dr. Riddell's and his own observations in widely separated portions of the State. The first of these was at the base of and included in his Austin limestone, as he had noticed them at Austin, and the other was the "fish beds" which, upon his brother's representations with the marly clay or Red River group, he erroneously placed at the base of his section.‡ There is no record that Dr. B. F. Shumard, ever visited the Denison region himself and this duplication and misplacement of the various members of his section is due to this fact.

I have traced the continuity and identity of these shales with the Eagle Ford horizons of my section, and have seen them resting by most perfect contacts upon the top of the Lower

* Sir Charles Lyell expressed the opinion that the fossils of the New Jersey Cretaceous beds of which this division is the equivalent, on the whole agree most nearly with those of the upper European series from the Maestrich beds to the Gault inclusive. In his Cours Elémentaire de Paléontologie, Alcide d'Orbigny refers the New Jersey beds as well as those of Nebraska (Upper Missouri), Arkansas, Texas (Rœmer's classification), and Alabama, all to his Senonian, the equivalent of the White Chalk and Maestricht beds of the old world.

Pictet, in his Traité de Paléontologie, also refers most if not all of the New Jersey Cretaceous fossils to the era of the White Chalk of Europe. See Cretaceous Paleontology, Meek. pp. xliii-xlvii.

† Trans. St. Louis Acad. Science, vol. i, 1860.

‡ I have explained the error in a review of Dr. G. G. Shumard's Red river observations. See this Journal, Jan. 1887.

Cross Timber (Dakota) beds in the Denison region, or, where the latter are absent, as at Austin, owing to erosion or non-deposition, directly upon the Comanche series, which demonstrates their position to be in the middle, and not at the bottom of the Texas Cretaceous as B. F. Shumard placed them. I have verified by personal observations the occurrence of most of the following forms in these shales at Austin and Eagle Ford, and New Braunfels:

Ostrea congesta.
Ostrea anomiaformis Roem.
Exogyra columbella Meek.
Lucina sublenticularis Shum.
Lucina (*Cyprimera*) *crassa* Meek.
Avicula irridescens Roem.
Inoceramus mytilodes Mant. Roem.
Inoceramus problematicus Schlot
Inoceramus deformis M. & H.
Scaphites semicostatus Roem.
" *texanus* Roem.
Ammonites percarinatus Meek and Hall.
**Ammonites graysonensis* Shum.
**Ammonites Meekianus* Shum.
Barbatia Shum.
Arca, sp. nov.?
Anomia, sp. ind.
And many fish remains.

The relative position, identity of faunal and lithologic features, and much stratigraphic data confirm the opinion previously expressed, that they are the equivalent of Meek and Hayden's 2 and 3, or Niobrara and Benton. I believe them to be the direct geographic continuation of the same geologic sediments, especially as seen by Newberry in northwestern New Mexico, together with the underlying Dakota sandstone which are represented by the Lower Cross Timber beds in northern Texas.

The contact of these shales with the over- and underlying groups is beautifully displayed along the south banks of the Colorado, opposite Austin; and in the east bank of Shoal Creek in the city itself, where there is a complete faunal and stratigraphic break between the shales just as Meek observed between the Pierre and Niobrara beds in the northwest and of which it can truly be said here as he said of the same formations there, that "the most strongly marked paleontological break in the Upper Cretaceous section is at the line separating the Niobrara from the Fort Pierre group, and that the beds above this horizon represent the upper or White Chalk and those below it the lower or gray chalk and perhaps also in part the Upper Greensand of English geologists."*

No equivalent of this division is found east of the Texas region, only a few of the vertebrate fish remains, belonging to species that have a wide geologic range, having been found in the Gulf and north Atlantic regions. This fact adds confirma-

* Cret. Pal., xlvi, xlvii.?

tion to a theory of the considerable hiatus between the deposits of the basal Eutaw clays and part of the Mississippi section above them.

The Lower Cross Timber series (Dakota sandstone of Shumard, Trans. St. Louis Acad., vol. ii, 1862) which underlie these shales in northern Texas, are entirely missing south of Waco, and hence do not appear at Austin. Whether this is due to their having been eroded away before the deposition of the shales, or to their having never been deposited, the writer does not feel prepared to state.

I have also traced the continuity of the Lower Cross Timber (Dakota sandstone?) division from the Texas Pacific railroad to Red river in the vicinity of Denison, and demonstrated their identity with the arenaceous group of Shumard's section, which with the so-called Marly clays he placed erroneously at the base of the whole Texas section. A year after the publication of his original section Dr. Shumard decided these arenaceous beds to be equivalent to the No. 1 (Dakota sandstone of Meek and Hayden.)

Concerning the relative age of the Dakota sandstone of the Rocky Mountain region, with which these beds in Texas are probably identical, Meek says: "Up to this time we also know of no single species being common to it and any of the beds above; but then we as yet know but comparatively few species of animal remains from this rock; one of these, however, belongs to the Cretaceous genus Leptosolen while the other shells are allied to Cretaceous species and unlike Jurassic forms. In addition to this the modern affinities of the numerous leaves of the higher types of dicotyledonous trees found in it, present a strong objection to the adoption of the conclusion that it may belong to a lower horizon than the Upper Greensand of British geologists; while its position directly below beds almost beyond doubt representing the lower or Gray Chalk, precludes its reference to any higher stratigraphical composition. Consequently we have long regarded it as most probably representing in part, if not the whole, of the Upper Greensand." The fossils described by Dr. B. F. Shumard from the Red river country include forms from horizons between the basal portion of the Rotten limestone of Division A, such as the *Ostrea belliplicata*† Shum. (including the Eagle Ford shales at the Lower Cross Timber beds) and from the top portion of the Comanche series, such as *Ammonites Swallovii*, etc. These horizons have not been fully studied but they represent all the

* In the vicinity of Denison the upper part of the Comanche series, the Lower Cross Timber sands, and the Eagle Ford shales succeed each other almost inseparably, so that there, instead of the sharp lines of demarcation between the three groups as at Austin, we have a gradual transition between all the beds.

† *Ostrea Blackii*, of White.

sediments between the well defined upper and lower deep marine groups and they constitute the middle division of the Cretaceous. I therefore present their fauna as a whole without detailed attempt at separation.

Ostrea anomiaformis Roem.
Ostrea congesta Con. ?
Ostrea belluplicata Shum.
Ostrea Blackii White.
Exogyra columbella Meek.
Barbatia, sp. nov.
Cucullæa millestriata Shum.
Nucula bellastriata Shum.
Nucula Haydeni Shum.
Nucula serrata Shum.
Lucina sublenticularis Shum.
Cyprimera crassa Meek.
Crassatella parvula Shum.
Dione ("*Cytherea*") *lamarensis*,
Tapes Hilgardi Shum.
Venilia (*Cyprina*) *Laphami* Shum.
Venus sublamellosus Shum.
Corbula Tuomeyi Shum.
Gervilia Mudgeana White.
Gerviliga regaria Shum.
Aguillaria? Cumminsi White.
Avicula irridescens Roem.
Inoceramus capulus Shum.
Inoceramus mytilopsis Con.
Inoceramus mytiloides Mant.
Nearea alæformis Shum.
Inoceramus problematicus Schlot.
Cylichna minuscula Shum.
Neritopsis biangulatus Shum.
Tornatella texana Shum.
Ringicula acutispira Shum.
Ringicula subpellucida Shum.
Scalaria lamarensis Shum.
Cerithium, sp. nov.
Baculites gracilis Shum.
Scaphites semicostatus Roem.
Scaphites texanus Roem.
Ancyloceras annulatum Shum.
Ammonites percarinatus M. & H.
A. Graysonensis Shum.
A. inaequiplicatus.
A. Meekianus Shum.
A. Swallovii Shum.
Fish remains.
Dicotyledonous leaves.

The Lower Division of the Texas Cretaceous.

The harder limestones, seen underneath the Lower Cross Timber beds at Fort Worth and Denison and the shales at Austin, and forming the face and plateau of the escarpment, are the undoubted top of the Comanche* series of my former paper. This great formation, which constitutes the face of the escarpment and the great plateau at its top, covers or once covered the whole of the central region as far west as the Rocky Mountain region. This group of strata embraces thousands of feet of deep marine sediments and extends over an immense area in Texas. At San Marcos, New Braunfels, Austin, and many other places throughout the central region, the strata are beautifully shown. Four miles northwest of the latter city the banks of the Colorado afford a vertical exposure of over 700 feet, and yet these are only the topmost strata of

*The name Comanche is given to this series owing to the fact that it was at the town of that name that I first studied it, and that the Central Denuded Region of Texas, where the formation is found, was the home of the Comanche Indians.

the series. The strata dip rapidly to the southeastward. While resembling the Rotten limestone of the Black Prairie region in color, a fact which has prevented its differentiation by previous observers, they are entirely different in hardness, structure, stratification, and all other respects*. The strata consist of white and yellow limestones, greatly varying in hardness, somewhat subcrystalline or chalky in places, and under a lower power they are seen to be composed of minute loosely-cemented calcite crystals and occasional Foraminifera. Toward the basal portion there are some thin bands of firm gray crystalline limestones, much resembling quartzite in firmness and opalescence. Between the limestone strata there are usually white calcareous marls or shales, of nearly the same color. Sometimes there are horizons of flint nodules, and rarely beds of pulverulent chalk. The thickness of the individual strata vary from over a hundred feet at the mouth of the Pecos river, to less than one foot in the vicinity of Fort Worth and Denison. The rock structure of this lower formation, although crumbling far more readily, does not yield as easily to solution as does that of the Upper Cretaceous of the Black Prairie region. It breaks into fragments under the expansion and contraction incident to daily extremes of temperature, to which fact is due the rugged outlines of the buttes, mesas and cañons in the central or denuded region as opposed to the gentle undulations of the Black Prairie region where the exposures of this formation in Texas are found.

The Central Denuded Region.

The borders of the central region in which the Comanche series is found present varying sharpness. The northern half is bounded upon the west by the westwardly receding line of the Llano estacado, and upon the east by the eastwardly receding line of the Rotten limestone of the Upper Cretaceous of the Black Prairie region. This recession of the borders in opposite directions is not apparent in the southern half of the region, where the denudation has not degraded and removed the harder limestones which constitute the eastward faces, scarp and plateau of the Austin New Braunfels non-conformity of the eastern boundary to the level of the Black Prairie region, as has been done along the northern portion of the same edge, while the former scarp of the staked plains has been entirely removed along the southern half of the western border.

* Governor Roberts, although utterly unaware of the geologic relation, is the first man who clearly noted this difference and fitly distinguished the two regions as the "soft" and the "hard" lime rock regions, respectively. See "A Description of Texas; its Advantages and Resources," by Oran M. Roberts. St. Louis, 1881.

Within the Central denuded area this newly defined group of the American Cretaceous is beautifully shown, every foot of its thickness and that of the Paleozoic strata upon which it generally rests, having been exposed by the excessive atmospheric denudation, showing its contacts with the over- and underlying formations. The process of this denudation in Texas is exactly similar to that of the high plateaus of Utah and Colorado, and the description given by Powell of aridity and erosion in his "Exploration of the Grand Cañons of the Colorado," pp. 170–171, is equally applicable to it, except that here in Texas the sudden heavy rainfalls are more frequent, and the different resistance of the sedimentary rocks causes a difference in topographic effect. In my paper on the Cross Timbers I have sufficiently described the northeast quarter of this central region and shown how the strata in going from east to west, are successively exposed in descending series from the marine Tertiary to the Paleozoic. The latter are exposed along a north and south axis, from the Red River to Colorado, by the removal of the overlying Cretaceous. The northwest quarter of the region is occupied by the red beds, or alleged "Jura-Trias," with occasional patches of the Cretaceous preserved upon it, in the shape of isolated buttes.

The southern half is still covered by the chalky limestones of the Comanche series of the Cretaceous, which, in addition to having been thicker originally than in the northern portion, have not suffered so much from the destructive denudation. The thickness of this formation rapidly decreases to the northward and I am inclined to believe that the strata in Texas and the Indian Territory represent only the northern shallowing of the great sediments developed more fully in Mexico and Central and South America. The thickness of the Comanche series, while not exceeding 500 feet along the Fort Worth section, at Austin must be fully 2,000, and still farther southwestward I believe it must approach 5,000. In the southern portion of the region the individual strata, as seen at the mouth of the Pecos river, are hundreds of feet in thickness; at Austin the thickest strata do not exceed fifteen feet, while at Fort Worth and Denison they seldom reach two feet. The members of this series possess sufficient diversity to divide it into many minor divisions, but this should not be attempted until several years more of thorough stratigraphic study of the whole is made. Provisionally I have divided it into a lower and upper division which are called the Fredericksburg* and the Washita

* See "Texas" and "Kreidebildungen von Texas?" for the first descriptions of the Fredericksburg strata, by Dr. Ferd. Roemer. The Washita strata are first mentioned by Dr. G. G. Shumard in Marcy's Exploration of the Red river of Louisiana, but better defined by Marcou in the Pacific Railroad Report of the 32° Parallel, octavo edition.

divisions after the typical localities of each, and where they were first noticed and described. While there is a great faunal and stratigraphic continuity between these two temporary divisions, nearly every species of the essentially deep sea fauna has a horizon of greatest culmination which will serve as land marks to the perfect section of the future. There are also certain specific differences between the faunas of the two divisions that mark them well, each having many characteristic forms of its own.

The Washita Division.

The upper half or Washita division is preserved only in a limited belt, seldom exceeding twenty miles in width, adjacent and parallel to the western border of the Black Prairie region. Its strata are the same as mentioned but not defined by Roemer from the Waco camp,* ten miles west of New Braunfels, by Dr. B. F. Shumard at old Fort Washita, Indian Territory, from which it takes its name,† and as has been more fully described by Jules Marcou from Comet creek, in the same vicinity. I have traced the formation from the vicinity of Fort Washita to San Antonio, and have good authority for its occurrence westward of the latter place to the Rio Grande, beyond Eagle Pass. The strata are of great uniformity of deposition, throughout, except that they are thinner in the northern portion of the exposures, where, from Fort Worth to Fort Washita, and especially at Denison, they make a gradual transition from deep-sea limestones to alternating limestones and shales, and then from shales to the littoral sand and clay deposits of the Lower Cross Timbers (Dakota Sandstone?), representing the termination of the long period of deep-sea sediments that marked the Comanche series. The following fossils have been found in this Washita division of the Comanche series, as far as I have been able to verify by careful field investigation:

Fauna of the Upper, or Washita Division.

Astrocœnia guadalupæ Roem.
Terebratula wacoensis Roem.
T. choctawensis Shum.
T. leonensis Con.
Holaster simplex Shum.
Holaster comanchesi Marcou.
Toxaster elegans Shum.
Cidaris hemigranosus Shum.
Pyrinia Parryi Hall.
Ophioderma? sp. nov.
Ostrea carinata Lam., Roem.
Exogyra arietina Roem.
Plicatula incongrua Con.
Ostrea crenulimargo Roem.
O. quadriplicata Shum.
O. diluviana Linn., White.

* "Texas," pp. 377; Kreidebildungen von Texas, p. 18.

† Dr. B. F. Shumard partially described this division, but misinterpreted its stratigraphic position in his section.

O. Marshii Marcou.
O. subovata Shum.
Gryphæa sinuata, var. *americana* Marcou.
Exogyra Valkeri White.
Gryphæa Pitcheri Mort.
var. *navia* Con.
var. *forniculata* White
var. *dilatata* Marcou.
Lima wacoensis Roem.
L. leonensis Roem.
L. Kimballi Gabb.
Neithea occidentalis Con.
Pecten quadricostatus Roem.
P. duplicostatus Roem.
Neithea cometa D'Orb.
? *N. Wrightii* Shum.
Janira fleuriausiana D'Orb.*
Lucina, sp. ind.
Trigonia, sp. ind.
Cardium hillanum Sowb.
Astarte texana Con.
Slearnsa ? *robinsi* White
Crassatella lineata Shum.
Gervillopsis ("*Dalliaconcha*") *invaginata* White.
Panopæa subparallela Shum.
Panopæa texana Shum.
Pachyma austinensis Shum.
Pachyma? compacta White.
Pinna, sp. ind.
Inoceramus, sp. ind.
Caprina crassifibra Roem.
Caprina guadalupæ Roem.
Caprina occidentalis Con.
Caprina planata Con.
Caprina quadrata Con.
Caprina texana Roem.
Requienia texana Roem.†
R. bicornis Meek.
R. patigiata White.
R. Romeri Gabb.
Hippurites texanus Roemer.
Natica? (*Tylostoma?*) *prægrandis* Roem.
Nerinea, sp. ind.
Pleurotomaria austinensis Shum.
Turritella marnochii White.
Cinulia, sp. nov.
Apporhais, sp. nov.
Nautilus neocomensis D'Orb.
Hamites Fremonti Marcou.
Ancyloceras, sp. nov.
Turrillites brazosense Roem.
Ammonites acutocarinatus Roem., Shum.
Ammonites Belknapi Marcou.
A. brazosensis Shum.
Ammonites geniculatus Lea.
Ammonites leonensis Con.
Ammonites Shumardi Marcou.
Ammonites Swallovi, Shum.
Ammonites vespertinus Mort.
A. texanus? Roem.

The Fredericksburg Division.

The provisional line of geologic demarcation between the two divisions is the Caprina limestone of Shumard. This is the horizon of greatest resistance in the Comanche series. It consists of more massive and firmer semi-crystalline limestones than those above and below it, and does not yield so readily to denudation, so that it is preserved in many places as the cap-rock of extensive mesas and buttes. Wherever it is preserved there will be found below it the strata which have been sufficiently described by Roemer from near Fredericksburg, consisting of softer crumbling, gritty limestones and lime marls. These strata were also well described by Shumard as the

* I have found this form at Austin, and see no reason for making it a new species.

† Probably identical with *Caprotina lonsdalli* D'Orb.

"Caprina limestone," the "Comanche Peak Group," and the "Caprotina" (Requiena) limestone, and his sections of Packsaddle Mountain, Burnet County, and Comanche Peak, Hood County, will apply to this division wherever it is exposed, as it is of great uniformity throughout.

The buttes or mesas of Central Texas, where the best exposures are found, locally mistermed "mountains" and "peaks," are unique and peculiar to the region through which they are distributed. They are low, truncated protuberances, usually circular in outline. Their tops are invariably flat, and the sides generally slope at an angle of forty-five degrees. They seldom exceed three hundred feet above the surrounding level, and are the most prominent landmarks of the region. The chief of these are Comanche Peak, Hood County; Johnson's Peak, Bosque County; Round Mountain, Comanche County; Santa Anna Peak, Coleman County; Kiowa Peak, Hardeman County; Castle Mountains, Tom Greene County; Double Mountains, on the head waters of the Brazos; Antelope Hills, on the boundary of the Panhandle and Indian Territory; Packsaddle Mountain, Burnet County; Church Mountain, Runnels County, and hundreds of others. In geological and general features they are all alike, being remnants of a great formation that once covered the whole region. Their simple structure consists of perfectly horizontal deep marine sediments, the cap stratum of which is the hard Caprina limestone of Shumard (siliceous limestone of Roemer). This Caprina limestone occupies a very low horizon in a Cretaceous section, and it is evident that structurally it is a plane of greatest resistance of the Fredericksburg series, which covers, and was once covered by, softer strata than its own. Most of them are situated in the deep, worn river valleys, or around the edge of the Paleozoic exposures. They usually stand upon a level prairie region of limited extent, which are underlaid by thinner and firmer limestones, constituting another plane of resistance. When the latter is worn through, the Carboniferous, Jura-Trias, or whatever formation underlies the Cretaceous at the particular locality, is soon exposed. The section of Packsaddle Mountain, Burnett County, made by B. F. Shumard is almost identical with the other buttes wherever I have examined them. This uniformity over so wide an area is owing to the uniformity of the sediments.

The following fauna, which is a revision of that first published by Roemer from Fredericksburg, and by Shumard from the three synonymous divisions of his section, before mentioned, is found in this lower provisional division:

Fauna of the Lower or Fredericksburg Division.

Orbitulites texanus Roem.
Gryphæa Pitcheri Mort. (Type form.,
G. Pitcheri Mort.? Marcou.
Exogyra texana Roem.
Ostrea, sp. ind.
Anomia, sp. ind.
Janira occidentalis Con.
Cardium brazösense Shum.
Cardium Hillanum Sow.
C. texanus Con.
C. coloradoense Shum.
C. multistriatum Shum.
C. sancta-sabea Roem.
Cytherea? Shum.
Pholadomya sancta-sabæ Roem
Pholadomya pedernalis Roem.
Lima wacoensis Roem.
Arcopagia texana Roem.
Cypricardia pedernalis Roem.
Trigonia crenulata (?) Roem., Lam.
Solen irradians Roem.
Astarte lineolata Roem.
Cardita eminula Con.
Avicula convexo-plana Roem.
Avicula pedernalis Roem.
Mytilus tenuitesta Roem.
Homomya alta Roem.
Corbula occidentalis.
Corbis, Roem.
Modiola concentrico-costellata Roem.
Modiola pedernalis Roem.
Pinna, sp. ind., Roem.
Leda, sp. ind., Roem.
Venus, sp. ind., Roem.
Thracia, sp. ind., Roem.
Panopara Newberryi Shum.
Actæonella dolium Roem.
Scalaria texana.
Phasianella? perovata Shum.
Phasianella tumida.
Globiconcha coniformis Roem.
Globiconcha? elevata Shum.
Rostellaria (*Eulima*) Shum. *subfusiformis.*
Natica (*Lunatia?*) *pedernalis.*
Natica? (*Lunatia*) *acutaspira* Shum.
Nerinea acus, Roem.
Nerinea, sp. ind., Roem.
Avellana? texana Shum.
Turritella, seriatim-granulata Roem.
Cerithium? bosquense Shum.
Cerithium? sp. ind., Roem.
Pleurotomara, sp. ind., Roem.
Solarium? sp. ind., Roem.
Heteraster (*Toxaster*) *texanus* Roem.
Holectypus planatus Roem.
Cyphosoma texana Roem.
Pseudodiadema texana Roem.
Ammonites acuto-carinatus Shum.
Ammonites? pedernalis von Buch (not Binkhorst).

The basal contacts of this division have been observed in numerous places, and present many variations. West of the 99th meridian it usually rests upon the red beds of the Jura-Trias. East of this it usually rests directly upon the undoubted Carboniferous, excepting in the Archæan area of Burnett and surrounding counties, where, according to Mr. W. F. Cummins, it can be seen resting on the Carboniferous, the Silurian, the Cambrian, and in places upon the granite, all of which shows an eroded exposure of many formations previous to the subsidence resulting in its deposition. In the trans-Pecos region the formation may be seen resting upon the almost vertical strata of the upturned Paleozoic. The basal, or Dinosaur sands of my section, which are interpolated

between the Fredericksburg division and the undoubted Carboniferous, are the shore detritus of the Mesozoic sea when it bordered upon the Carboniferous continent. The lowest marine fauna of this division is seen in Parker county and careful study of the same may prove Jurassic affinities.

Several years of most careful study of the stratigraphy of the whole of the Comanche Series fully confirms its position to be lower than the strata of the Lower Cross Timber beds, which Shumard, White and other authorities have asserted to be identical with the Dakota Sandstone of Meek and Hayden, and hence lower than any of the hitherto described marine groups of the American Cretaceous. The fossils of the upper division are in most cases well preserved, and the species readily distinguishable. Those of the lower division are very poorly preserved, especially the bivalve mollusca, the shell structure having been destroyed, rendering it exceedingly difficult to obtain even the generic characters.

There is an apparent continuity of interlocking faunas throughout the series, and a few forms, such as *Cardium* (*Protocardia*) *hillanum* and its allies, *Neithea occidentalis* Con., and the *Gryphœa pitcheri* Mort., range throughout. A remarkable fact, however, is that with the exception of the last mentioned fossil, not a single species is known to pass from the Comanche series into the upper formations, and even this is not positively known to do so. The only other fossil which is ascribed to the Upper Cretaceous is the *Ammonites pedernalis* VonBuch, which has been confounded by some authors with the *Placentaceras lenticularis* of Meek, a form characteristic of the Upper Cretaceous of nearly all the world. It is an entirely different species however, as has been shown by Mr. Meek. Another remarkable feature of the fauna of the Comanche series is that the species have no affinities or resemblances in the other Cretaceous formations of the United States, while, on the other hand, they present remarkable analogies to certain well-known forms of other countries, especially eastern Europe and tropical America. This fact has always been so apparent, that many of the authors of species described from Texas (none of whom save Jules Marcou suspected their true paleontologic horizon), frankly confessed that they could distinguish no difference between the American and European forms, and gave them the same names, as in the case of the *Ostrea diluviana* Linne, White, the *Gryphœa sinuata*, var. *Americana* Marcou, and many of Roemer's and Shumard's species. The new names bestowed upon other forms were accompanied by expressed doubts as to their value, while nearly all the authors gave such close analogies that modern biologists would not hesitate to consider the differences varietal, and not specific.

A review of the fossils of the Comanche series shows that the Ammonitidæ, which are especially abundant in the Washita Division, consist of the sharp-keeled and flexuous-ribbed forms so characteristic of the Lower Cretaceous, while the genus Crioceras (Ancyloceras) is represented by several species absolutely indistinguishable from Neocomian forms. The characteristic *Ammonites pedernalis* Von Buch (not Binkhorst), of the Comanche Division, is an aberrant archaic ceratitic form. The only brachiopod of the Comanche series, which occurs about midway in the Washita Division, the *Terebratula wacoensis* Roemer, was confessed by its author to be very near *T. semiglobosa* Sow., of the Neocomian. The Echinodermata all belong to genera which had their origin in or previous to the Lower Cretaceous, and have great affinities to the European forms, one of which is almost indistinguishable from the characteristic *Toxaster complanatus.* The Ostreidæ mostly belong to the deep-water, and now extinct sub-genera Gryphæa, Exogyra, and Alectryonia, a great number of which present none of the confusing variation of the later Ostreidæ. The anomalous *Gryphæa Pitcheri*, which is an exception to the last generalization, instead of having been originally described from New Jersey and being the most widely distributed form of the Cretaceous in the United States, as has been asserted, was originally described from Indian Territory, and is almost if not entirely limited to the Comanche Series, except a few forms from the overlying shales of the Rocky Mountain region. This is a Jurassic form, which has continued up into the Cretaceous of this country, and the naviate variety is almost indistinguishable from the *G. arcuata* of the European Lias. It was chiefly upon the evidence of the *Exogyra texana* and the *Ostrea carinata* that Roemer made this Comanche series belong to the Upper Chalk of Europe, but according to modern biologic methods these forms really belong to two well-marked ostreidean types that have been described under a host of names, which have the widest vertical range of any Cretaceous forms, and the Texas individuals bear much greater resemblance to the basal varieties of the Neocomian than to those of the Chalk. The Caprotina of Roemer is the genus Requienia, characteristic of the European Lower Neocomian, and the widely distributed single species characteristic of the Fredericksburg Division of the Comanche series, which has been described under many synonyms, is hardly distinguishable from the characteristic *Caprotina Lonsdalii* D'Orb., of the European Neocomian. The Rudistes, Nerineas, Pleurotomarias, Globioconchas, and other forms, while not decisive, are corroborative of the low position of the Comanche series. This opinion is strengthened, furthermore, by the occurrence of many other forms, and the absence of any species characteristic of the upmost Cretaceous.

While the upmost strata of the Washita division have many species characteristic of the lower Middle Cretaceous of Europe,* I believe that there is no room to doubt that the deep marine fauna of the whole of the Comanche series shows a wonderful similarity to well-known forms of the European strata below the upper portions of the Middle Cretaceous, and bearing special resemblance, in its lower portion, to the Neocomian. The presence of Middle Cretaceous forms in the upper portion of the Washita division, near its transition into the Dakota sandstones, is confirmatory of Meek's opinion that the latter could not have been older than the upper portion of the Middle Cretaceous. Not only is the Comanche series older, but the faunal and stratigraphic breaks between it and the Upper Cretaceous are complete, and show in this a great similarity to the European Cretaceous, where, according to Etheridge, "of the total number of fossils from the 'Lower Greensand' or Upper Neocomian (upwards of 400) only 65 (or 16 per cent) pass to the Upper Cretaceous (chiefly to the Gault). This paleontological break with unconformity between the Lower Greensand and the Gault in the south of England, and the top of the Speeton clay and succeeding Red chalk or Hunstanton limestone in Norfolk, clearly show that a definite boundary line exists between the lower and upper parts of the Cretaceous system of England."

Dr. Ferdinand Roemer, after having accepted the erroneous stratigraphic theory, pointed out in the previous pages, that this series rested upon the Upper division, instead of unconformably beneath it, endeavored to make the paleontology fit this hypothesis, much to the obscuration of our Cretaceous geology. From the foregoing evidence, I believe there is room to doubt the correctness of his opinion that "the Cretaceous strata of Texas altogether belong to the Upper Chalk, i. e., the chalk above the Gault, and indeed so much so that they correspond to the horizon of the White Chalk ('Etage Senonien,' D'Orbigny), and to the upper part of the Chloritic Chalk ('Etage Turonien,' D'Orbigny) of Europe; but, in addition, include the lower or Neocomian."†

I have used the three divisions which a fortunate series of non-conformities have displayed at Austin, for the purpose of clearer contrast, but farther north in the Fort Worth and Denison region the sediments are more continuous from the first approach of the Mesozoic seas upon the Carboniferous continent as seen in the Dinosaur sands to the Marine Tertiary. This section reveals two transitions from littoral deposits of sands to deep-sea chalks and back again, the shallows of the Dakota (Lower Cross Timber) sands representing the medial stage.

* Juronien, of D'Orb.

† Kreid. von Texas, p. 25.

It is probable that the present Austin New Braunfels nonconformity continued to Red river, and that future stratigraphic study will demonstrate this. It is nearly obliterated by a more excessive denudation there, but a portion of the old plateau exists in the Grand Prairie, between the Upper and the Lower Cross Timbers. This plateau is clearly the remnant of an elevation previous to the deposition of all the hitherto marine Cretaceous of America, although it was submerged again in parts, as is seen by the deposition of later formations upon it.

I have shown by methods of stratigraphic paleontology that we have in Texas not only the most complete section of the purely marine formations of the Cretaceous of the United States, but we have a well-defined series of marine strata of much lower horizon than heretofore supposed to exist in this country, which when they are properly studied, will eliminate the supposed hiatus of deposition which has been thought to exist between Jurassic or Wealden, and middle upper portion of the Middle Cretaceous of this country. In fact, we have in Texas, along the region described in this paper, the most of a section of the Cretaceous and other Mesozoic which, from its approximate completeness, must in the future be looked upon as the standard of comparison in the study of the Mesozoics of this country, just as the Paleozoic formations of the Appalachian region are accepted as our standard for earlier time.

For the present we can only divide the American Cretaceous section into generalized Upper, Middle and Lower divisions. When, by modern methods of stratigraphic paleontology, this Texas region is more thoroughly studied, we shall have a simple comprehensive section of the entire period, which will serve as a standard of comparison, owing to its greater development and transitional geographic position for both the Rocky Mountain and Atlantic regions, and as a basis for an intelligible and rational nomenclature. Until this is done all attempts at a fixed nomenclature of the American Cretaceous must remain unsatisfactory and provisional.

SCIENTIFIC INTELLIGENCE.

I. Physics and Astronomy.

1. *Annalen der Physik und Chemie*, No. 8^b, for 1887, contains the following articles; *On a new polar effect of magnetism upon the heat produced by the electric current in certain substances;* by Albert von Ettingshausen.—The author finds that a temperature difference obtains in a magnetic field and discusses the

bearing of this phenomenon upon the Hall effect. The paper includes a mathematical discussion of the subject by Boltzmann.

On the Electromotive force developed in metal plates, carrying a heat current, by a magnetic field; by WALTHER NERNST.—This paper is a continuation of the work of Ettingshausen, by a student in the laboratory of Kohlrausch.

On the effect of Magnetism upon electric discharges in rarefied gases by LUDWIG BOLTZMANN.—A flattened Geissler tube was placed with its broadest section perpendicular to the lines of magnetic force. Two glass tubes leading out of the magnetic field served to connect the electrodes of a galvanometer. The apparatus thus imitated the arrangement used by Hall in the investigation of his phenomenon. A transverse effect was discovered analogous to that in metals. Air behaved as bismuth or gold.

Observations upon the electrical conductivity of metals by means of the induction balance; by A. OBERBECK and J. BERGMANN.—The authors show that Hughes's balance in general is not a trustworthy instrument. Using an electro-dynamometer instead of a telephone, and thin plates of metal they obtained good results.

Theory of the induction Balance; by A. OBERBECK.—Mathematical discussion.

On the electrical conductivity of pure water and its temperature coefficient; by E. PFEIFFER.—The effect of the chemical constitution of the glass confining vessels is noted; also, change of resistance with time and other conditions.

Electrical relations of Rock Salt; by FERDINAND BRAUN.—Its dielectric constant is studied. It was found to behave as an isotropic substance in this relation. It conducts electricity from 11 to 23 times better than paraffine.

Studies of Salt Solutions; by C. BENDER.

Two fundamental investigations upon the laws of Pyroelectricity; by EDUARD RIECKE.

On Hydrogen superoxide arising in electrolysis of dilute sulphuric acid at the anode; by FRANZ RICHARZ.

On the applicability of Joule's law to electrolytes; by HANS JAHN.

Magnetic circular polarization in cobalt and nickel; by H. E. J. G. DUBOIS.

Gliding of the electric spark on the surface of water; by J. SPIESS.—This is a study of Lichtenberg's figures on the surface of water which is covered by lycopodium.

On the influence of ulti a violet light on electrical discharges; by H. HERTZ.—The author shows that ultra violet light increases the striking distance and length of spark of a Ruhmkorff coil. If one draws apart the poles of a Ruhmkorff coil so that the spark no longer passes, and then lights an electric light from one to four meters distant, the spark again passes and stops, when the electric light is extinguished.

On the compressibility of dilute salt solutions; by W. C. RÖNTGEN and J. SCHNEIDER.

On the taking up of water vapor by solid bodies; by Dr. T. IHMORI.

On water of crystallization of dissolved cobalt salts; by JACOB KALLIR.

An answer to W. Voigt's remarks upon elliptical polarization of the reflected light of transparent bodies; by W. WERNICKE.

Projection of the true image of a vibrating string; by J. PULUJ.

Answer to the remarks of Franz Koláček on the freezing point; by ROBERT VON HELMHOLTZ.

Water of Crystallization; by W. MÜLLER-ERZBACH.

On the height of clouds; by W. KOHLRAUSCH.—The author noticed a peculiar cloud and measured its height, obtaining a height of sixty kilometers. J. T.

2. *The production, properties and uses of very fine threads.*—The production of extremely fine threads of glass, quartz and other materials has been brought to a high degree of perfection by Mr. C. V. BOYS. The method which he found most satisfactory in its results was the following: a fragment of drawn out glass was attached by sealing wax to the tail of an arrow made of a piece of straw a few inches in length; the glass was heated to a high temperature in the middle and while the end was held in the fingers the arrow was projected by a cross bow of pine held in a vise and with a trigger that could be pulled by the foot. With every successful shot the thread was continuous from the piece held in the hand to the arrow 90 feet off, a glass thread 90 feet long and $\frac{1}{10,000}$ inch in diameter being obtained. The diameter was almost perfectly uniform for the greater part of the length. Instead of holding the glass tail in the hand, a little bead of glass may be fused on the end and, when the arrow is shot, the inertia of the bead is sufficient to draw out the thread in the same way.

The author has also experimented upon a number of minerals and found that while some behave like glass, others will not draw at all being either perfectly fluid like water or when cooler perfectly rigid. Thus corundum, hornblende, zircon, rutile, cyanite, fluorite will not draw at all; on the other hand emerald and almandine will draw but care is needed to obtain the proper temperature. Orthoclase draws readily, but quartz though troublesome and requiring more force yields remarkably successful threads of extreme minuteness, in some cases tapering down to a size beyond the power of the microscope to resolve. These minute threads have some peculiar properties which the author proposes to investigate, they are highly elastic and it is suggested that they may be advantageously used for torsion-threads. They may also be preferable to spider lines for the cross wires in the eye-pieces of microscopes and other instruments.—*Phil. Mag.*, xxiii, 489.

3. *Photography by Vital Phosphorescence.*—DR. JOHN VANSANT has continued his experiments in photography by phospho-

rescent light (this Journal, xxxiii, 307) and obtained the curious result of an image formed by the light from fire flies. A dozen of the fire flies were enclosed in a wide-mouthed vial, in which they emitted their momentary flashes of greenish-yellow light, in the familiar way, stimulated by a gentle shaking. A sensitive bromide dry plate was placed beneath an ordinary glass negative of a landscape, and the vial of insects inverted over the back of the negative. The plate was exposed to the light emitted by fifty of the flashes and then developed; a distinct positive image of the negative picture was the result, the plate being somewhat yellow stained as if from too long an exposure.—*St. Louis Photographer*, July, 1887.

4. *Annual Reports of the Board of Directors of the Chicago Astronomical Society, together with report of the Director of the Dearborn Observatory for* 1885 *and* 1886; *with papers by* Professors SAFFORD (*Nebulæ*), COLBERT (*Lunar apsides and Sirius*), *and* HOUGH (*Double Star Catalogue, and printing chronograph*). Chicago, 1887, pp. 50.—The work with the great equatorial of this observatory has been principally given to difficult double stars and the planet Jupiter.

5. Professor PICKERING has decided to publish short articles upon Astronomical and Meteorological subjects prepared at the Harvard College Observatory as successive numbers of a series which will constitute the 18th volume of the Annals of the Observatory.

The first article is a table of the magnitudes of the stars used in the various Nautical Almanacs. The table contains 800 stars, and gives their magnitudes derived from the Harvard, the Argentine, the Wolff and the Oxford Photometries. It will be of interest both to regular and to amateur astronomers as an independent catalogue of the brighter stars, and as an index to the stars in the several almanacs.

The second paper consists of a comparison of the Oxford, the Harvard and the Bonn Uranometries.

6. *Resultados del Observatorio Nacional Argentino en Córdoba durante la direccion del* D^or^ BENJAMIN A. GOULD; JUAN M. THOME, *Director.* Vol. VI, 4°, Buenos Aires, 1887.—This sixth volume contains the Cordoba observations made during the year 1875. The 7th and 8th volumes containing the zone catalogue have been already published.

II. GEOLOGY AND MINERALOGY.

1. *Damming and erosion by Greenland ice.*—Mr. J. E. MARR, in an interesting paper on the work of ice sheets as illustrated by the Greenland glacier (Geol. Mag., April, 1887), has the following paragraphs on the damming of valleys by ice, and the amount of erosion in some valleys.

The very conspicuous manner in which the Greenland valleys are stopped up by ice is also worthy of notice in connection with

the glacial theory of the origin of the Parallel Roads of Glenroy. The Jacobshavn glacier stops up both ends of a valley running parallel with its course, converting it into a lake which is separated from the glacier throughout the greater part of its length by a "Nunatak." The lower end of another valley considerably to the south of this is stopped by the ice-sheet, and the valley converted into a lake (Tasersiak), which is drained by a river running over the col at the head of the valley into the Strömfjord, just as in the case of the Märjelen See, only the Greenland lake is much larger than this. A similar lake drains into the N. Isortok fjord, and another into that of Alangordlia. Two similar lakes are formed to the east of Sermilik fjord, and several small ones to the east of Björnesund. North of the Frederikshaab glacier is a valley running north and south, the mouth of which is stopped by the Frederikshaab glacier, whilst a tongue of ice flows through a col situated half-way up the valley and bars the valley, one part of the tongue of ice flowing a small distance to the north, and another to the south, thus causing the conversion of the valley into two lakes. On the east of the Frederikshaab glacier is the lake Tasersuak, bounded on the north by the "Nunatak" Kangarsuk, and stopped at its lower end by the Frederikshaab glacier, and having a tongue of the ice-sheet entering into it at the upper end.

The erosive power of an ice-sheet is well seen by a glance at the observations made upon the rivers which flow into the fjords of Nagsugtok and Isortok, and which have their origin at the ends of the tongues of ice which occupy the valleys continuous with these fjords. The river from the first contained only 200–225 grams of mud per cubic meter of water in the month of July, while the second in the month of June enclosed 9129 to 9744 grams. This is compared with the amount carried by the Aar where it emerges from the glacier; it there contains only 142 grams. The great difference presented by the rivers which fall into the two fjords is attributed to the fact that the ice moves with much greater speed toward the fjord of Isortok than toward that of Nagsugtok. It is calculated that the quantity of fine mud carried into the former of these fjords amounts to 4062 million kilograms per day. This mud is deposited in the interior of the fjord, which is filled up to such an extent in its upper portion that even flat boats cannot pass up it. What a powerful machine for the formation of the fine clay of "till" is here.

2 *Variations in water-level in enclosed Seas.*—PROFESSOR SUESS has recently discussed the phenomenon of variation in the relative heights of water and land, more especially for the Baltic Sea, and with reference to the different hypotheses that have been advanced to explain it. He decides in favor of the opinion held by Nordenankar, that the phenomenon is not due to elevation of the land but is essentially one of variations in the height of the water as caused by the varying precipitation and outflow. The

extended observations that have been made show that the oscillations in water-level go on with great uniformity, that they are more marked in the north, and that years with a positive average alternate with those with a negative, the latter being now in excess. Attention is also called to the fact that a similar conclusion has been reached for the Black Sea by Haun and Köppen. For the Mediterranean the conditions are somewhat similar, though here the amount of salt is greater than in the ocean, increasing in the neighborhood of Crete and the African coast, since the inflow of the streams through the Bosphorus and Gibraltar does not suffice to supply the place of the water evaporated. Accurate measurements of level have shown that the surface of the Mediterranean lies a little deeper than that of the ocean, it resembling somewhat a shallow funnel with greatest depth coinciding with the region where the water is most salt. A continual equilibrium is not to be expected but rather variations of the water condition especially toward the apex of the funnel. The greatest recorded changes of the coast-line are to the southwest of Crete, and amount to 20 to 23 feet (negative) as given by Spratt. Even on the Spanish and French coast where the amount of salt is almost the same with that of the ocean, variations of 0·4 to 1·02 meters have been recorded.—*Akad. Wien.*, *Anzeiger*, xvi.

3. *Unconformability between the Animikie and the Vermilion Series;* by ALEXANDER WINCHELL. (Communicated to the Editors in a letter dated Aug. 20, 1887.)—I beg to announce that while engaged in work for the Minnesota Geological Survey, I have discovered the unconformable superpositions of the Animikie on the slates of the Vermilion series. The Animikie flint schists dipping five degrees southward, have been traced by me to within *seven feet* of sericitic argillites of the Vermilion series, dipping northeast about 67 degrees. I will communicate particulars hereafter.

4. *Catalogue of the Fossil Mammalia in the British Museum.* Part IV, containing the Order Ungulata, Suborder Proboscidea; by RICHARD LYDEKKER, B.A., F.G.S., etc. 236 pp. 8vo, with 32 woodcuts. London, 1886. — This volume completes Part IV. The collection of remains of the Proboscidea in the British Museum is without a rival, and this gives special importance to the annotated catalogue. The following *on the vertical distribution of the Proboscidea* is from pages xii, xiii.

The most remarkable point in regard to the vertical distribution of the Proboscidea is their apparently sudden appearance in the Middle Miocene of Europe, where they are represented by *Dinotherium giganteum* and *Mastodon angustidens.* Although the former is evidently a generalized form connecting the *Elephantidæ* with the less aberrant Ungulates, yet it cannot be regarded as the direct ancestor of any known member of that family; and the latter is to all intents and purposes a perfect Elephant, in the widest sense of that term. Our comparatively full knowledge of the Lower Miocene and Upper Eocene Mammalian faunas of the

greater part of Europe and North America (where the Proboscidea are unknown till the Pliocene) renders it almost certain that neither of those regions was the home of the direct ancestors of the *Elephantidæ*; and we must therefore look forward to the discovery of mammaliferous Lower Miocene or Upper Eocene strata in some other region of the (probably Old) World, which may yield these missing forms. There is, however, but little chance of the occurrence of such beds in India, and our main hope must therefore be directed to other parts of Asia, or Africa, if indeed these regions were ever populated in early Tertiary times by the larger Mammalia.

In regard to geographical distribution there appears to be considerable evidence in favor of an easterly migration of the Mastodons having taken place from Europe to India; while the restriction of the Stegodont group of Elephants to the latter country and the regions to the eastward, points to the conclusion that the transition from the Mastodons to the higher Elephants took place in those regions; from which we may also infer that there subsequently ensued a westerly migration of these higher forms to Europe, and finally on to North America, where the true Elephants did not make their appearance till the Pleistocene, and then appear to have been represented only by two species, one of which ranged over the greater part of the higher latitudes of the northern hemisphere.

5. *Mineral localities in the Western United States.*—At recent meetings of the Colorado Scientific Society various new occurrences of minerals have been described. Mr. W. B. Smith mentions the rare mineral dioptase from a new locality near Riverside, Pinal county, Arizona; it is found in well-formed prismatic crystals, the largest $3{\cdot}5^{mm}$ in length and $0{\cdot}5^{mm}$ in thickness. He also notes alabandite in crystals on Snake river, Summit county; manganite on Devil's Head mountain, Douglas county; a black ferriferous rutile from near St. Peter's Dome in the Pike's Peak region; epidote and garnet and a corundum schist from Chaffee county. Mr. R. M. Pearce describes the occurrence of enargite at the Gangon mine, Montana; erinite and other copper arsenates, also pharmacosiderite, from the Tintic district, Utah.

III. Miscellaneous Scientific Intelligence.

1. *British Association.*—The meeting of the British Association for 1887, opened at Manchester on the 31st of August. The number of tickets sold approached 4,000, exceeding the number of any former year. The grants to investigators during the past year aggregate more than $10,000. The proceeds available for the coming year from the large attendance at this meeting will be still greater.

The inaugural address of the president, Sir Henry E. Roscoe, alluded, in its opening remarks, to the honorable mention of the name of the great Manchester chemist, John Dalton, in the presi-

dential address of Lord Francis Egerton at the meeting in Manchester of 1842, and referred then to Joule, another Manchester philosopher, as the worthy successor of Dalton. Sir Henry then proceeded to consider "what light the research of the past fifty years has thrown on the subject of the Daltonian atoms: First, as regards their size; secondly, in respect to their indivisibility and mutual relationship; and thirdly, as regards their motions."

As to the size of atoms, Dalton believed them immeasurably small; but, in 1865, Loschmidt, of Vienna, reached the conclusion that the diameter of an atom of oxygen or nitrogen was 1/10,000,000 of a centimeter, and a few years later, William Thomson demonstrated that the distance between the centers of contiguous molecules is less than 1/5,000,000, and greater than 1/1,000,000,000 of a centimeter. As regards atomic weights, and the idea of hydrogen as a unit, conclusions of Dalton and Prout, the present position of science is that the weights in many instances are not exact multiples of hydrogen; and yet they are so near that "we are constrained to believe that the approximations cannot be a mere matter of chance; that there is a reason for it which science will yet discover." New relations between groups of elements also have been ascertained, as that which, through Mendelejeff, has proved to be prophetic of new discoveries of elements, and which has appeared to point to the conclusion that the elements have been derived from a common source. The indivisibility of atoms, assumed to be a fact by Dalton, has hence become a subject for investigation and argument. But actual division has not yet been accomplished by the highest terrestrial temperatures, that of the electric spark; nor has it been proved by the study of the sun's conditions, nor by the investigations of the spectra of the fixed stars; so that the idea of evolution of the elements is not yet proved. On this important point we cite here the words of the address.

"How far, now, has this process of simplification been carried? Have the atoms of our present elements been made to yield? To this a negative answer must undoubtedly be given, for even the highest of terrestrial temperatures, that of the electric spark, has failed to shake any one of these atoms in two. That this is the case has been shown by the results with which spectrum analysis, that new and fascinating branch of science, has enriched our knowledge, for that spectrum analysis does give us most valuable aid in determining the varying molecular conditions of matter is admitted by all. Let us see how this bears on the question of the decomposition of the elements, and let us suppose for a moment that certain of our present elements, instead of being distinct substances, were made up of common ingredients, and that these compound elements, if I may be allowed to use so incongruous a term, are split up at the temperature of the electric spark into less complicated molecules. Then the spectroscopic examination of such a body must indicate the existence of these common ingredients by the appearance in the spark-spectra of these elements of

identical bright lines. Coincidences of this kind have indeed been observed, but on careful examination these have been shown to be due either to the presence of some one of the other elements as an impurity, or to insufficient observational power. This absence of coincident lines admits, however, of two explanations—either that the elements are not decomposed at the temperature of the electric spark, or, what appears to me a much more improbable supposition, each one of the numbers of bright lines exhibited by every element indicates the existence of a separate constituent, no two of this enormous number being identical.

Terrestrial analysis having thus failed to furnish favorable evidence, we are compelled to see if any information is forthcoming from the chemistry of the sun and stars. . . . . . .

"Since Bunsen and Kirchhoff's original discovery in 1859, the labors of many men of science of all countries have largely increased our knowledge of the chemical constitution of the sun and stars, and to no one does science owe more in this direction than to Lockyer and Huggins in this country, and to Young in the New England beyond the seas. Lockyer has of late years devoted his attention chiefly to the varying nature of the bright lines seen under different conditions of time and place on the solar surface, and from these observations he has drawn the inference that the matching observed by Kirchhoff between, for instance, the iron lines as seen in our laboratories and those visible in the sun, has fallen to the ground. He further explains this want of uniformity by the fact that at the higher transcendental temperatures of the sun the substance which we know here as iron is resolved into separate components. Other experimentalists, however, while accepting Lockyer's facts as to the variations in the solar spectrum, do not admit his conclusions, and would rather explain the phenomena by the well-known differences which occur in the spectra of all the elements when their molecules are subject to change of temperature or change of position.

"Further, arguments in favor of this idea of the evolution of the elements have been adduced from the phenomena presented by the spectra of the fixed stars. It is well known that some of these shine with a white, others with a red, and others again with a blue light; and the spectroscope, especially under the hands of Huggins, has shown that the chemical constitution of these stars is different. The white stars, of which Sirius may be taken as a type, exhibit a much less complicated spectrum than the orange and the red stars; the spectra of the latter remind us more of those of the metalloids and of chemical compounds than of the metals. Hence it has been argued that in the white, presumably the hottest, stars a celestial dissociation of our terrestrial elements may have taken place, whilst in the cooler stars, probably the red, combination even may occur. But even in the white stars we have no *direct* evidence that a decomposition of any terrestrial atom has taken place; indeed we learn that the hydrogen atom, as we know it here, can endure unscathed the inconceivably fierce

temperature of stars presumably many times more fervent than our sun, as Sirius and Vega.

"Taking all these matters into consideration, we need not be surprised if the earth-bound chemist should, in the absence of celestial evidence which is incontestable, continue, for the present at least, and until fresh evidence is forthcoming, to regard the elements as the unalterable foundation-stones upon which his science is based."

Another new contribution to the question of the decomposability of the elements is that made by Crookes, who, by means of the spectra of the phosphorescent light of some rare earths under an electric discharge in a vacuum, ascertained the possible presence of new elements, showing, as in the case of yttria, either that the bodies yielding the different phosphorescent spectra are different elementary constituents of the substance which we call yttria; or, in consideration of their yielding the same spark-spectrum, "adopting the very reasonable view that the Daltonian atom is probably, as we have seen, a system of chemical complexity, and to this adding the idea that these complex atoms are not all of exactly the same constitution and weight, the differences, however, being so slight that their detection has eluded our most delicate tests with the exception of this one of phosphorescence in a vacuum." A third possible explanation is suggested by Marignac—the presence of traces of foreign bodies, introduced in the course of the thousands of separations which have to be made before the differences become manifested. Dalton showed that gases diffuse into one another; and Graham later, but over fifty years since, that the relative rates of diffusion are inversely proportional to the square roots of their densities. But Joule, in his papers on the mechanical equivalent of heat, and on the constitution of electric fluids, expressed the movements in figures, and established "the foundation of chemical dynamics and the basis of thermal chemistry; and he added the further fact that "when electrical energy is developed by chemical change a corresponding quantity of chemical energy disappears." Another step onward, in the direction of electrical chemistry has been taken in establishing the fact that an intimate relation exists between chemical activity and electrical conductivity.

Dalton was the first to point out the existence of distinct compounds consisting of the same constituents in the same percentage quantity. On this as a starting point, the science of organic chemistry has been built up through the addition of the principle as to the combining capabilities of elements, or their valency, the nature and relations of radicals, and the principle of substitutions. Further results have come from consequent advances in organic synthesis. Sir Henry Roscoe treats briefly also of the progress made in the theory of animal heat and other questions connected with pathological chemistry.

This brief abstract of the presidential address is made from the full report of it in *Nature* of September 1. *Nature* of September 8,

(the last number thus far received), contains the address of Sir Robert Hall, president of the Physical Section, on "that part of the science of theoretical mechanics, which is usually known as the Theory of Screws," under the title "A Dynamical Parable"—that of Edward Schunck, Ph.D., president of the Chemical Secton—on the directions in which the chemistry of the future will probably be developed, under which he spoke of facts and problems in the physiology of plants, and others relating to the decomposition of organic and organized matters and ferments; and that of Henry Woodward, F.R.S., president of the Geological Section, reviewing the field of research in geology, and pointing out some of the special needs of the science.

2. *Memoirs of the National Academy of Sciences;* Vol. III, Part 2.—This volume, recently issued, contains the following papers: Contributions to meteorology, by Elias Loomis, pp. 1–66, with 16 plates; On Flamsteed's stars "observed but not existing," pp. 69–83, and Corrigenda in various star catalogues, pp. 87–97, by C. H. F. Peters; Ratio of meter to yard, by C. B. Comstock, pp. 101–103; composite photography as applied to craniology, by J. S. Billings, and on measuring the cubic capacity of skulls, by W. Matthews, pp. 105–116 with 20 plates; on a new craniophore for use in making composite photographs of skulls, by J. S. Billings and W. Matthews, pp. 119–120, 4 plates; on the Syncarida, pp. 123–128, 2 plates, on the Gampsonychidæ, pp. 129–133, 1 plate, and on the Anthracaridæ, by A. S. Packard, pp. 135–139, 2 plates; also on the Carboniferous xiphosurous fauna of North America by the same author, pp. 143–157, 4 plates; on two new forms of polyodont and gonorhynchid fishes from the Eocene of the Rocky Mountains by E. D. Cope, pp. 161–165, 1 double plate; notes on the third memoir, page 45, part 1, by A. M. Mayer.

3. *Smithsonian Institution and the Fish Commission.*—It is expected that Professor Langley, who for the past year has been the Assistant Secretary in the Institution, will be made Secretary. Mr. G. Browne Goode has been appointed Commissioner of the Fisheries and no better appointment could have been made.

OBITUARY.

SPENCER FULLERTON BAIRD, the Zoologist, the Commissioner of the Fisheries under the U. S. Government, and the Secretary of the Smithsonian Institution, died at Wood's Holl, Massachusetts, on the 19th of August.

Mr. Baird was born at Reading, Pennsylvania, in the year 1823. He graduated, in 1840, from Dickinson College, at Carlisle, Pa., and five years later, in his twenty-third year, was made Professor of Natural History in that Institution. When but fourteen he made, in connection with his brother, Wm. M. Baird, a collection of the birds of Cumberland Co., Pa., manifesting thus early that zeal for natural science which determined his future course in life; and in 1844, the two published, in this Journal, a list of the Cumberland County birds, having in view,

as the authors say, the bearing of such publications of local faunæ on the laws which regulate the distribution of species on the globe. This paper is followed by another on two new species of Tyrannutæ from the same region.* Mr. Baird's collection of birds, fishes, mammals, etc., became greatly extended by long excursions on foot in the Adirondacks and elsewhere which his great powers of physical endurance enabled him to carry on and for distances, some days, of nearly 60 miles.

The writer first made the acquaintance of Mr. Baird in 1843, when working over the corals of the Wilkes Exploring Expedition, then arranged in the hall of the Patent Office; and he had for some time daily proof of his enthusiasm in science, his earnestness as a worker, his scientific knowledge and his generous disposition—the latter manifested, among other ways, in his gift of a translation of Ehrenberg's Memoir on the Corals of the Red Sea, which he had in the meantime prepared. This was the commencement of his interest in the Expedition collections that afterward came under the charge of the Smithsonian Institution when he was assistant Secretary.

Professor Baird's appointment to the position of assistant Secretary in the Institution was made in 1850. It was hailed with great satisfaction by those interested in the natural sciences; for it was thus made sure that the Institution, which had so admirable a representative of the physical sciences in the secretary, Professor Henry, would be ably conducted as regards other scientific departments. It was just the place for him and he was just the right man for the place. His breadth of knowledge in the sciences of nature, his sympathy with other workers over the land, his indefinite powers of work, his systematic methods, and his eagerness to make the Institution national in the highest sense of the term and also scientifically and practically useful, produced their effects; and happily there was full support of the assistant secretary in his views and plans by Professor Henry. Part of these plans consisted in the furthering of Government explorations for scientific discovery and observations in the Territories; and for many years after 1850 such expeditions were in the field adding greatly to the knowledge of the structure, features, resources, floras and faunas, etc., of the country, and gathering specimens for a great national museum. The arrangements and selection of men for such expeditions, were largely in Mr. Baird's hands, and much of the success attending them was due to his wisdom. The gathering of specimens finally resulted in 1857, in the union of the collection with those of the Wilkes Exploring Expedition in a common museum, supported by funds from the General Government but under the charge of the Smithsonian Institution.

Dr. Baird's study of American birds led to his commencing in 1846 the preparation of a Synonymy of North American Birds;

* Cited from the Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, 1843.

and, later, to various publications, among them a "Catalogue of North American Birds," published by the Smithsonian in 1858–1859; a "Review of American Birds in the Museum of the Smithsonian Miscellaneous Collections," begun in June, 1864; a Memoir on the "Distribution and Migrations of Birds," presented to the National Academy in 1865, and printed in abstract (covering 31 pages) in volume xli (second series, 1866) of this Journal; and in conjunction with Mr. John Cassin, "The Birds of North America," issued in 1870; and, along with T. M. Brewer and R. Ridgeway, an illustrated work on the Birds of North America, in 1874. In the department of fresh-water fishes of North America a work was projected by Professor Agassiz and himself soon after the arrival of the former in the country, but nothing of it was ever published.

Dr. Baird also published papers on Reptiles, and in 1853 "an Annotated catalogue of North American Reptiles" was issued by Mr. C. Girard and himself, which contained descriptions of several new species of serpents. His publications on Mammals also were numerous, and included, in 1859, a volume of 764 pages quarto on "the Mammals of North America," several of whose two hundred and twenty species were before undescribed. An early laborious work, finished in 1851, was his "translation" of the text of the "Iconographic Encyclopedia," making four large volumes—which work as regards the second volume was "entirely re-written," the Botany, Fishes, Amphibians, Reptiles and Anthropology by himself, the Invertebrates by S. S. Haldeman, the Ornithology by John Cassin and the Mammals by C. Girard.

While carrying on his investigations and writing books and papers, he found time also for the multitudinous details connected with the Smithsonian Institution, its extended system of exchanges, the fitting out of exploring expeditions, the writing of his part of an annual Smithsonian report, and so on. To these duties were added in 1871, by appointment of the President of the United States, but without additional remuneration, those of Commissioner of Fisheries; and the practical working and success of this new department under the government attests to his wide knowledge and his executive ability. As another has said, "the services he rendered in this capacity in increasing the food-supply of the world would alone justify a national monument to his memory."

In 1878, on the decease of Professor Henry, Mr. Baird was appointed his successor as Secretary of the Institution, a place for which he was eminently fitted by his long and active experience in its affairs.

Professor Baird's large contributions to science brought him medals and honorary membership from various scientific academies abroad; and the connection of his name with thirty-three new genera and species of animals attests to the high appreciation of him by fellow-workers in zoology.

Incessant labor finally wore upon his health. "For some years he appears to have fully recognized the fact that his day as an active investigator was over, and he had contented himself with directing others. When he was sent as advisory counsel by the United States to the Halifax Fish Commission he prepared an essay on fish culture into which he threw all the wealth of his vast information and experience on this subject. He kept that manuscript unpublished, hoping to add to it, but recently put it in the press, and it is now in course of being printed, and will be a posthumous contribution of inestimable value to the history of the pursuit to which he gave so much time and attention. In like manner he lately placed the results of his ornithological studies in the hands of Professor Ridgeway, and they are now in course of publication by a leading Philadelphia firm. His life is rounded and his career has closed with a record of achievements that will grow in public estimation the more it is contemplated."

When he went in June last, to Wood's Holl, the chief summer station under the Commission of the Fisheries, he was much broken in health; and, although he rallied for a while, but a few weeks passed before the end came. His wife and his daughter survive him.

ALVAN CLARKE died on the 22d of August at Cambridge, in his eighty-fourth year, having been born at Ashfield, Massachusetts, March 8, 1804. The science of astronomy owes much to Mr. Clarke. Through his skill and judgment, dependent largely on delicacy of touch and sight, and the promptings of astronomical zeal started up by the discovery of some new double stars made with an instrument of his own construction, he became famous as a maker of telescopes, and had orders, more than he could fill, from foreign as well as American observatories. His discoveries led to correspondence with the English astronomer, Mr. W. R. Dawes, and afterwards to some years of study abroad between 1850 and 1860. His first large telescope, 18½ inches in diameter of object-glass is in the observatory at Chicago; one of 26 inches at the U. S. Observatory, Washington; another of the same size, at the Observatory of the University of Virginia; one of 32 inches, at the Pulkowa Observatory, Russia; and one of 36 inches at the Lick Observatory of California. The Russian telescope brought him a gold medal from the Czar. The manufacture of telescopes has been carried on by him in connection with his sons, George B. and Albert Graham Clarke, who have like skill and perfection of work.

APPENDIX.

ARTICLE XXXV.—*Notice of New Fossil Mammals;* by O. C. MARSH.

AMONG the large number of extinct mammals recently received at the Yale Museum from the West, are several of especial interest, as they serve to mark definite horizons in the Tertiary deposits east of the Rocky Mountains, or show important characters not before observed. A notice of some of these species new to science is given below, and more complete descriptions will appear elsewhere.

Bison alticornis, sp. nov.

This species of Bison is represented by various remains, the most important of which is the portion of a skull, figured below. This specimen, which may be regarded as the type, indicates one of the largest of American bovines, and one differing widely from those already described. The horn-cores, instead of being short and transverse, as in the existing bisons, are long and elevated, with slender, pointed ends. They have large cavities in the base, but in the upper two-thirds are nearly, or quite, solid. Their position is well shown in the cuts below, figures 1 and 2. The frontal region between the horn-cores is broad, somewhat convex, and very rugose.

FIGS. 1 and 2.

FIGURE 1.—Part of skull, with horn-cores, of *Bison alticornis*, Marsh; front view.
FIGURE 2.—The same specimen; seen from the left.
Both figures are one-eighth natural size.

The remains of this species are found in the sandstones of the Denver group, at the eastern base of the Rocky Mountains, where they indicate a well-marked horizon, which may be called the Bison beds. These deposits are more recent than the Equus beds, and are probably late Pliocene.

The locality of the type specimen is on the banks of Green Mountain Creek, near Denver, Colorado, where it was found by George L. Cannon, Jr., of Denver. Portions of the same specimen were subsequently secured by Whitman Cross of the U. S. Geological Survey. Other remains were obtained by G. H. Eldridge of the Survey, and all were sent to the writer for examination.

Aceratherium acutum, sp. nov.

Remains of the present species are abundant in one horizon of the Pliocene east of the Rocky Mountains, and a large number of fine specimens have been secured, which are now

Fig. 3.

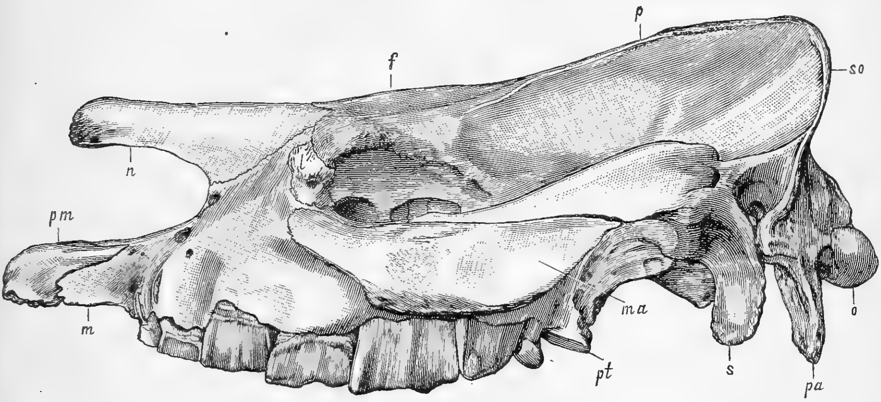


Fig. 4.

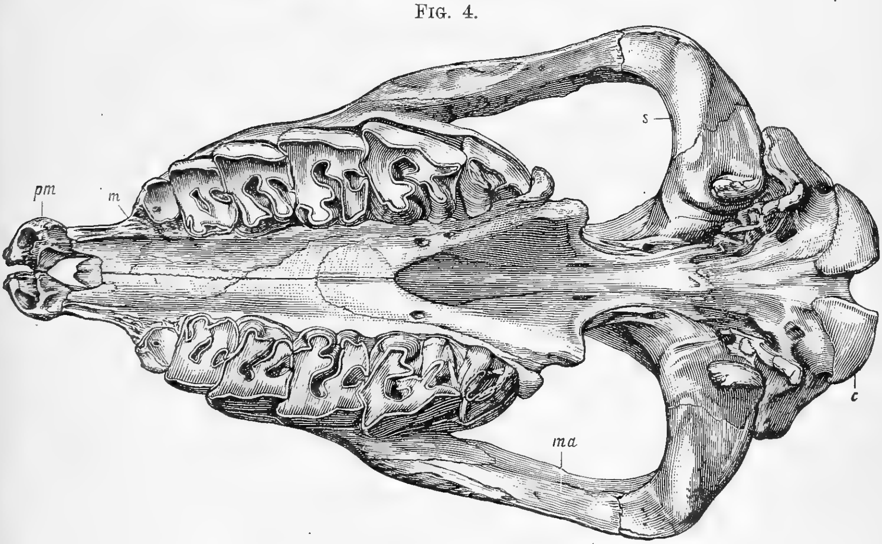


Figure 3.—Skull of *Aceratherium acutum*, Marsh; seen from the left.
Figure 4.—The same specimen; seen from below.
Both figures are one-fifth natural size.

in New Haven. The skull represented above, in figures 3 and 4, has been selected as the type. It is narrow at the base, with widely expanded zygomatic arches, and with the facial portion

tapering rapidly in front. There is a well-marked sagittal crest, and a strong constriction between the temporal openings. The frontal bones expand rapidly forward, and meet the broad, smooth nasals, which converge anteriorly into the pointed ends which have suggested the specific name. The paroccipital process is strong and elongate, and the post-glenoid is shorter and more massive. The premaxillary bones are weak, and project considerably beyond the end of the nasals. They each supported a single incisor.

A striking feature of the skull is the very large size of the molar teeth, which are well shown in figure 4.

There were no lower jaws found with the present skull, but in other specimens of this species, they are well represented. Each ramus is of moderate depth, the angle rounded, and the lower border gently convex below. On each side of the symphysis is a small incisor, and outside of this, a large, worn tooth, which is probably a canine. There is a short diastema, and behind this, are six robust teeth.

The locality of these remains is in Phillips County, Kansas, and the special horizon in which they occur so abundantly is in the Pliohippus beds of the Upper Pliocene. The specimens here described were obtained by J. B. Hatcher of the U. S. Geological Survey.

Brontotheridæ.

The large collections of the *Brontotheridæ* secured by the writer in his various expeditions in the West have been supplemented by important discoveries made during the last two years, mainly under the auspices of the U. S. Geological Survey. Remains of more than one hundred individuals, many of them with the skulls in good preservation, have recently arrived in New Haven, and are now under examination. The results of an investigation of the whole group will be brought together by the writer, in a monograph now well advanced toward completion. Some of the more important of the new forms are briefly described below, and these will all be fully illustrated in the monograph.

Brontops robustus, gen. et sp. nov.

The present genus is quite distinct from any of the forms previously described, and the type is the most perfect specimen of this group yet discovered. The skull and lower jaws are almost as perfect as in life, and the greater part of the skeleton has also been secured. The skull is large and massive, with widely expanded zygomatic arches, and short and robust horn-cores, projecting well forward. In general form, it resembles

the skull of *Brontotherium*, but may be readily distinguished from it by the dental formula, which is as follows:

Incisors $\frac{2}{1}$; canines $\frac{1}{1}$; premolars $\frac{4}{4}$; molars $\frac{3}{3}$.

The presence of four premolars in each ramus of the lower jaw is a distinctive feature in this genus. This character, with the single, well-developed incisor, marks both the known species.

The type species here described is one of the largest of the group, and the skeleton on which it is based is already represented on many plates of the monograph in preparation. The skull is about thirty-two inches (81 cm.), in length, and twenty-six and one half inches (67 cm.), across the zygomatic arches. The pelvis is over four feet (120 cm.), in width.

This unique specimen was discovered by the writer and H. C. Clifford, his guide, in 1874, near the White River in northern Nebraska. The geological horizon is in the upper part of the Brontotherium beds of the Lower Miocene.

FIG. 5.

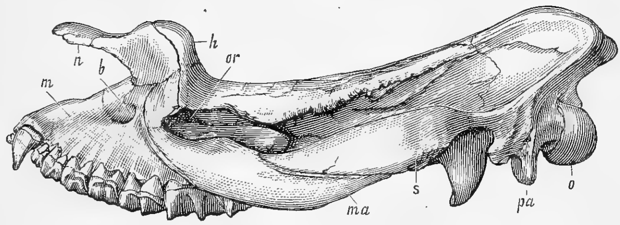


FIG. 6.

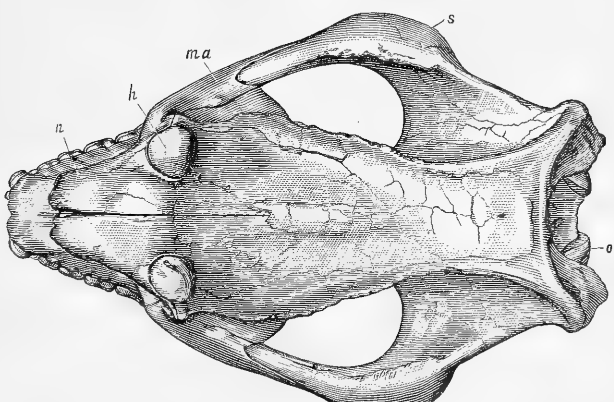


FIGURE 5.—Skull of *Brontops dispar*, Marsh; side view (young male).
FIGURE 6.—The same skull; top view.
Both figures are one-eighth natural size.

Brontops dispar, sp. nov.

A smaller species of this genus is represented at present by a nearly complete skull with lower jaws and entire dentition. The skull is less massive, and proportionately more elongate than in the type species, and the lower jaw more slender. The latter is shown below, in figures 7 and 8, which also illustrate some of the generic characters.

The skull of a young animal, apparently of this species, is represented in figures 5 and 6. The sutures are many of them distinct, especially those in the facial region, and thus the elements of the horn-cores, in this genus at least, can be readily determined. The front of the elevation is formed by the

FIG. 7.

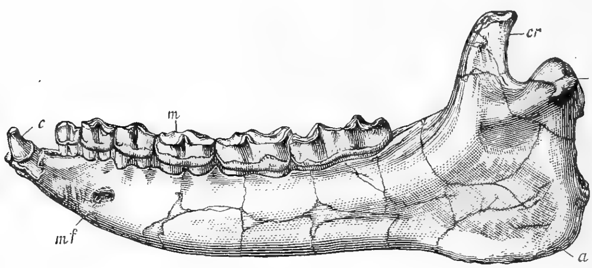


FIG. 8.

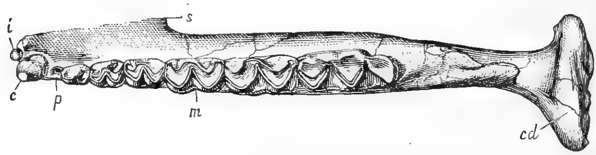


FIGURE 7.—Lower jaw of *Brontops dispar*, Marsh; side view.
FIGURE 8.—The same jaw; top view.
Both figures are one-eighth natural size.

nasal, and the main portion by the frontal. The maxillary contributes only the outer face of the base, but in some of the other genera, its share appears to be larger.

The specimens above mentioned were found in the Brontotherium beds of Dakota, by Mr. J. B. Hatcher of the U. S. Geological Survey.

Menops varians, gen. et sp. nov.

The present genus is most nearly related to *Diconodon*, and in its molar teeth agrees with that form. It differs in the

presence of two upper incisors on each side. The superior dentition is as follows:

Incisors, 2; canine, 1; premolars, 4; molars, 3.

In figure 9, below, is shown the type specimen, which is evidently the skull of a large adult male. Figure 10 represents a female skull apparently of the same species. The latter skull is much less robust, and the horn-cores are very small, although the dentition and sutures show that the animal was fully grown.

FIG. 9.

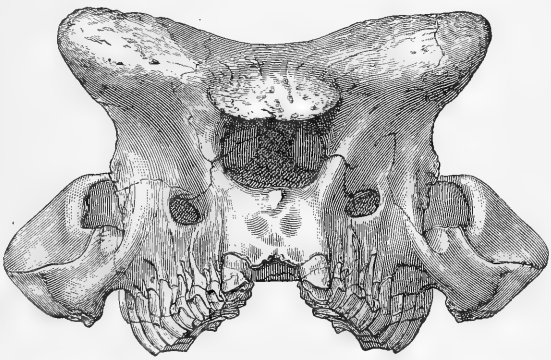


FIG. 10.

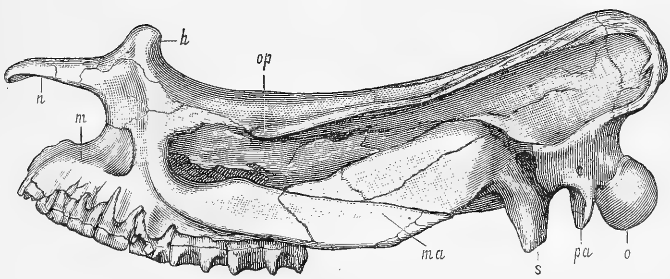


FIGURE 9.—Skull of *Menops varians*. Marsh; front view (male).
FIGURE 10.—Skull of same species; side view (female).
Both figures are one-eighth natural size.

The interesting specimen shown in figure 9 was obtained by Mr. George A. Clarke, from the Brontotherium beds of Dakota. The other specimen was found in the same region by Mr. J. B. Hatcher.

Titanops curtus, gen. et sp. nov.

This genus contains the largest members of the *Brontotheridæ*, and some of the last survivors of the group. They are distinguished from all the other known types, by the long, narrow skulls, lofty, flat horn-cores, and short nasals. The upper dentition corresponds nearly to that of *Brontotherium*; but the upper molars have all two inner cones.

FIG. 11.

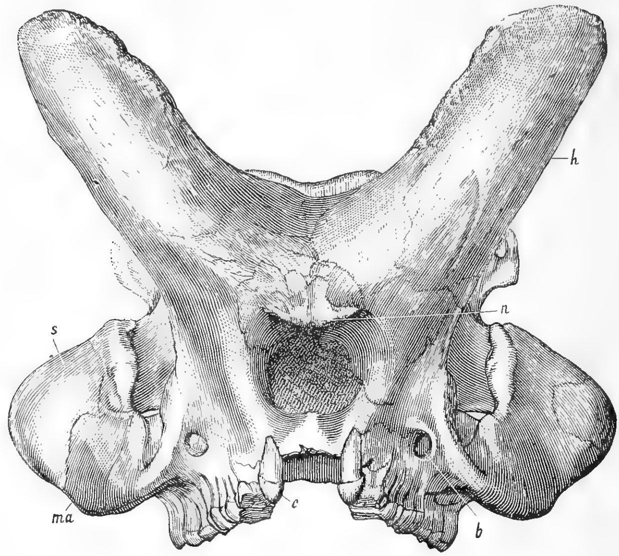


FIGURE 11.—Skull of *Titanops curtus*, Marsh; front view. One-eighth the natural size.

Figure 11 shows the front view of the type specimen, which indicates well the above features. The nasals are the shortest known in the group.

This specimen was obtained by the writer, in the lower Miocene of Colorado.

Titanops elatus, sp. nov.

A second specimen, about equal to the last in size, but representing a different species, is shown in figure 12. The nasals are much longer, and the occipital crest much higher, than in the type species. The zygomatic arches are unfortunately wanting, but the lower jaw is present, nearly in place. It shows no marked characters different from that of *Brontops*.

This specimen is from the Miocene of Dakota, and for important aid in securing it, the writer is indebted to Prof. F. R. Carpenter of the Dakota School of Mines.

FIG. 12.

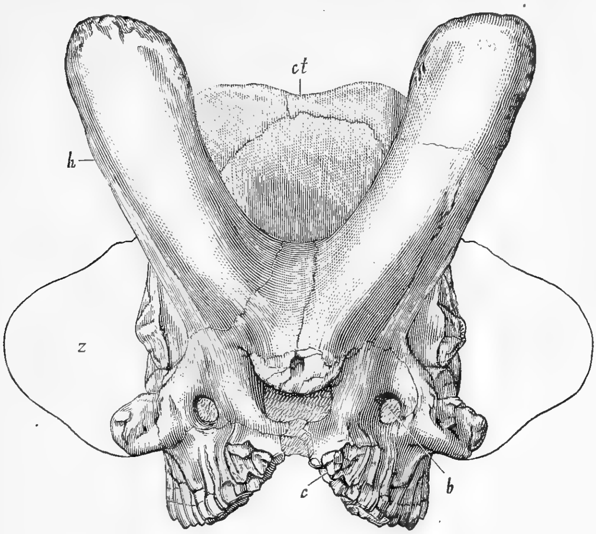


FIGURE 12.—Skull of *Titanops elatus*, Marsh; front view. One-eighth the natural size.

Allops serotinus, gen. et sp. nov.

Another genus nearly related to *Brontotherium* is represented at present by a well-preserved skull, and various other remains. This skull in its general form resembles that of *Brontotherium*, but differs in having only a single upper incisor, and the last molar has the posterior inner cone more strongly developed.

The superior dentition is as follows:

Incisor, 1; canine, 1; premolars, 4; molars, 3.

In the type specimen, the canine is small, extending but little below the premolars. There is no diastema. The upper premolars have a very strong inner basal ridge. The nasals are very wide, expand forward in the free portion, and are notched in front.

The entire length of this skull is thirty-one inches (79 cm.), the distance across the zygomatic arches twenty-one inches (53 cm.), and the length of the horn-cores about ten inches (25 cm.)

This specimen was found near the top of the Brontotherium beds in Dakota by Mr. J. B. Hatcher, who has done much by his discoveries to increase our knowledge of this group.

Yale College, New Haven, Sept. 24th, 1887.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

ERRATA.

Vol. xxxiv, page 227, line 12 from top, for MOREHEAD read MORELAND; line 30, for single read *simple;* line 32, for required read *acquired.*

Chas. D. Walcott,
U. S. Geological Survey.

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VOL. XXXIV.—[WHOLE NUMBER, CXXXIV.]

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[THIRD SERIES.]

ART. XXXVI.—*On the Relative Motion of the Earth and the Luminiferous Ether*; by ALBERT A. MICHELSON and EDWARD W. MORLEY.*

THE discovery of the aberration of light was soon followed by an explanation according to the emission theory. The effect was attributed to a simple composition of the velocity of light with the velocity of the earth in its orbit. The difficulties in this apparently sufficient explanation were overlooked until after an explanation on the undulatory theory of light was proposed. This new explanation was at first almost as simple as the former. But it failed to account for the fact proved by experiment that the aberration was unchanged when observations were made with a telescope filled with water. For if the tangent of the angle of aberration is the ratio of the velocity of the earth to the velocity of light, then, since the latter velocity in water is three-fourths its velocity in a vacuum, the aberration observed with a water telescope should be four-thirds of its true value.†

* This research was carried out with the aid of the Bache Fund.

† It may be noticed that most writers admit the sufficiency of the explanation according to the emission theory of light; while in fact the difficulty is even greater than according to the undulatory theory. For on the emission theory the velocity of light must be greater in the water telescope, and therefore the angle of aberration should be less; hence, in order to reduce it to its true value, we must make the absurd hypothesis that the motion of the water in the telescope carries the ray of light in the opposite direction!

On the undulatory theory, according to Fresnel, first, the ether is supposed to be at rest except in the interior of transparent media, in which secondly, it is supposed to move with a vel ociy less than the velocity of the medium in the ratio $\frac{n^2-1}{n^2}$, where n is the index of refraction. These two hypotheses give a complete and satisfactory explanation of aberration. The second hypothesis, notwithstanding its seeming improbability, must be considered as fully proved, first, by the celebrated experiment of Fizeau,* and secondly, by the ample confirmation of our own work.† The experimental trial of the first hypothesis forms the subject of the present paper.

If the earth were a transparent body, it might perhaps be conceded, in view of the experiments just cited, that the intermolecular ether was at rest in space, notwithstanding the motion of the earth in its orbit; but we have no right to extend the conclusion from these experiments to opaque bodies. But there can hardly be question that the ether can and does pass through metals. Lorentz cites the illustration of a metallic barometer tube. When the tube is inclined the ether in the space above the mercury is certainly forced out, for it is incompressible.‡ But again we have no right to assume that it makes its escape with perfect freedom, and if there be any resistance, however slight, we certainly could not assume an opaque body such as the whole earth to offer free passage through its entire mass. But as Lorentz aptly remarks: "quoi qui'l en soit, on fera bien, à mon avis, de ne pas se laisser guider, dans une question aussi importante, par des considérations sur le degré de probabilité ou de simplicité de l'une ou de l'autre hypothèse, mais de s'addresser a l'expérience pour apprendre à connaitre l'état, de repos ou de mouvement, dans lequel se trouve l'éther à la surface terrestre."§

In April, 1881, a method was proposed and carried out for testing the question experimentally.‖

In deducing the formula for the quantity to be measured, the effect of the motion of the earth through the ether on the path of the ray at right angles to this motion was overlooked.¶

* Comptes Rendus, xxxiii, 349, 1851; Pogg. Ann. Ergänzungsband, iii, 457, 1853; Ann. Chim. Phys., III, lvii, 385, 1859.

† Influence of Motion of the Medium on the Velocity of Light. This Journal, III, xxxi, 377, 1886.

‡ It may be objected that it may escape by the space between the mercury and the walls; but this could be prevented by amalgamating the walls.

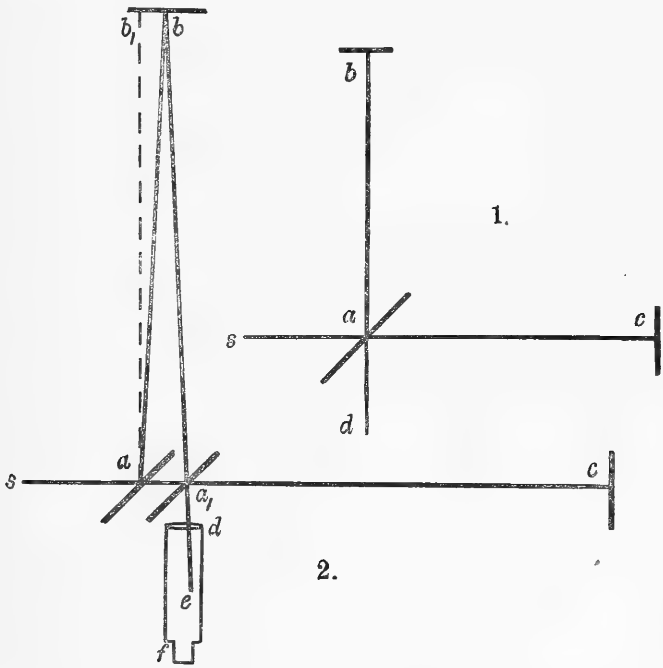
§ Archives Néerlandaises, xxi, 2me livr.

‖ The relative motion of the earth and the luminiferous ether, by Albert A. Michelson, this Jour., III, xxii, 120.

¶ It may be mentioned here that the error was pointed out to the author of the former paper by M. A. Potier, of Paris, in the winter of 1881.

The discusssion of this oversight and of the entire experiment forms the subject of a very searching analysis by H. A. Lorentz,* who finds that this effect can by no means be disregarded. In consequence, the quantity to be measured had in fact but one-half the value supposed, and as it was already barely beyond the limits of errors of experiment, the conclusion drawn from the result of the experiment might well be questioned; since, however, the main portion of the theory remains unquestioned, it was decided to repeat the experiment with such modifications as would insure a theoretical result much too large to be masked by experimental errors. The theory of the method may be briefly stated as follows:

Let *sa*, fig. 1, be a ray of light which is partly reflected in *ab*, and partly transmitted in *ac*, being returned by the mirrors *b* and *c*, along *ba* and *ca*. *ba* is partly transmitted along *ad*,



and *ca* is partly reflected along *ad*. If then the paths *ab* and *ac* are equal, the two rays interfere along *ad*. Suppose now, the ether being at rest, that the whole apparatus moves in the direction *sc*, with the velocity of the earth in its orbit, the direc-

* De l'Influence du Mouvement de la Terre sur les Phen. Lum. Archives Néerlandaises, xxi, 2[me] livr., 1886.

tions and distances traversed by the rays will be altered thus:— The ray *sa* is reflected along *ab*, fig. 2; the angle $bab_{,}$ being equal to the aberration $=a$, is returned along $ba_{,,}$ ($aba_{,}=2a$), and goes to the focus of the telescope, whose direction is unaltered. The transmitted ray goes along *ac*, is returned along $ca_{,,}$ and is reflected at $a_{,,}$ making $ca_{,}e$ equal $90-a$, and therefore still coinciding with the first ray. It may be remarked that the rays $ba_{,}$ and $ca_{,,}$ do not now meet exactly in the same point $a_{,,}$ though the difference is of the second order; this does not affect the validity of the reasoning. Let it now be required to find the difference in the two paths $aba_{,,}$ and $aca_{,}$.

Let V=velocity of light.
v=velocity of the earth in its orbit.
D=distance *ab* or *ac*, fig. 1.
T=time light occupies to pass from *a* to *c*.
$T_{,}$=time light occupies to return from *c* to $a_{,,}$ (fig. 2.)

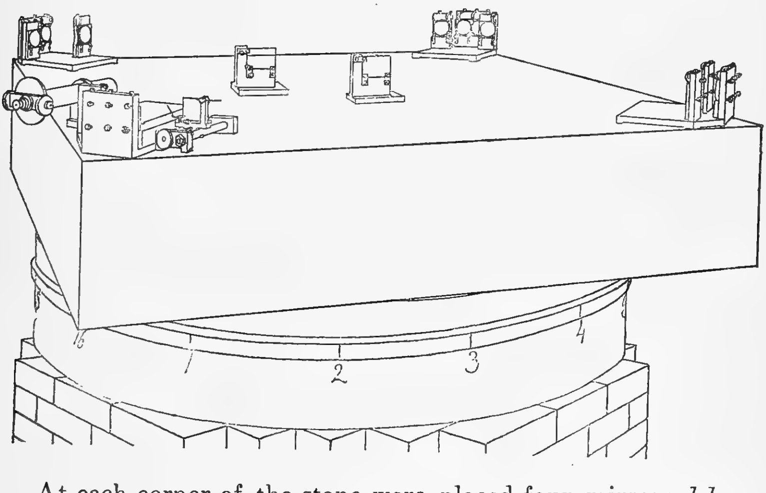
Then $T=\frac{D}{V-v}$, $T_{,}=\frac{D}{V+v}$. The whole time of going and coming is $T+T_{,}=2D\frac{V}{V^2-v^2}$, and the distance traveled in this time is $2D\frac{V^2}{V^2-v^2}=2D\left(1+\frac{v^2}{V^2}\right)$, neglecting terms of the fourth order. The length of the other path is evidently $2D\sqrt{1+\frac{v^2}{V^2}}$, or to the same degree of accuracy, $2D\left(1+\frac{v^2}{2V^2}\right)$. The difference is therefore $D\frac{v^2}{V^2}$. If now the whole apparatus be turned through 90°, the difference will be in the opposite direction, hence the displacement of the interference fringes should be $2D\frac{v^2}{V^2}$. Considering only the velocity of the earth in its orbit, this would be $2D\times10^{-8}$. If, as was the case in the first experiment, $D=2\times10^6$ waves of yellow light, the displacement to be expected would be 0·04 of the distance between the interference fringes.

In the first experiment one of the principal difficulties encountered was that of revolving the apparatus without producing distortion; and another was its extreme sensitiveness to vibration. This was so great that it was impossible to see the interference fringes except at brief intervals when working in the city, even at two o'clock in the morning. Finally, as before remarked, the quantity to be observed, namely, a displacement of something less than a twentieth of the distance between the interference fringes may have been too small to be detected when masked by experimental errors.

The first named difficulties were entirely overcome by mounting the apparatus on a massive stone floating on mercury; and the second by increasing, by repeated reflection, the path of the light to about ten times its former value.

The apparatus is represented in perspective in fig. 3, in plan in fig. 4, and in vertical section in fig. 5. The stone *a* (fig. 5) is about 1·5 meter square and 0·3 meter thick. It rests on an annular wooden float *bb*, 1·5 meter outside diameter, 0·7 meter inside diameter, and 0·25 meter thick. The float rests on mercury contained in the cast-iron trough *cc*, 1·5 centimeter thick, and of such dimensions as to leave a clearance of about one centimeter around the float. A pin *d*, guided by arms *gggg*, fits into a socket *e* attached to the float. The pin may be pushed into the socket or be withdrawn, by a lever pivoted at *f*. This pin keeps the float concentric with the trough, but does not bear any part of the weight of the stone. The annular iron trough rests on a bed of cement on a low brick pier built in the form of a hollow octagon.

3.

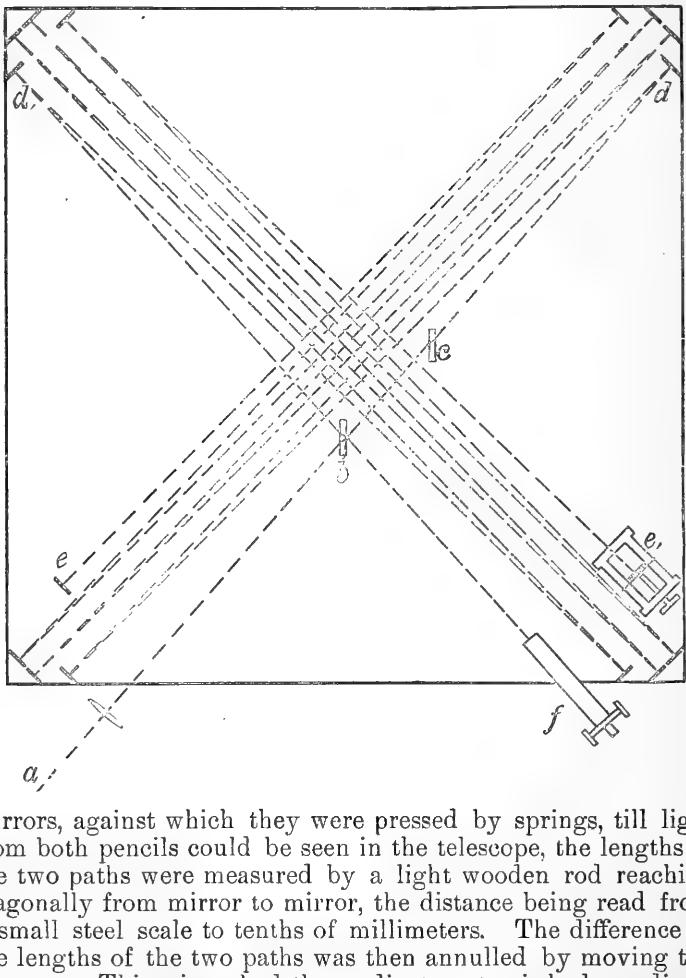


At each corner of the stone were placed four mirrors *d d e e* fig. 4. Near the center of the stone was a plane-parallel glass *b*. These were so disposed that light from an argand burner *a*, passing through a lens, fell on *b* so as to be in part reflected to $d_{\prime}$; the two pencils followed the paths indicated in the figure, *bdedbf* and $bd_{\prime}e_{\prime}d_{\prime}bf$ respectively, and were observed by the telescope *f*. Both *f* and *a* revolved with the stone. The mirrors were of speculum metal carefully worked to optically plane surfaces five centimeters in diameter, and the glasses *b* and *c* were plane-parallel and of the same thickness, 1·25 centimeter;

their surfaces measured 5·0 by 7·5 centimeters. The second of these was placed in the path of one of the pencils to compensate for the passage of the other through the same thickness of glass. The whole of the optical portion of the apparatus was kept covered with a wooden cover to prevent air currents and rapid changes of temperature.

The adjustment was effected as follows: The mirrors having been adjusted by screws in the castings which held the

4.

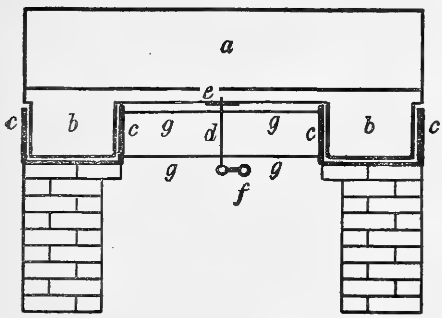


mirrors, against which they were pressed by springs, till light from both pencils could be seen in the telescope, the lengths of the two paths were measured by a light wooden rod reaching diagonally from mirror to mirror, the distance being read from a small steel scale to tenths of millimeters. The difference in the lengths of the two paths was then annulled by moving the mirror $e_{,}$. This mirror had three adjustments; it had an adjustment in altitude and one in azimuth, like all the other mirrors,

but finer; it also had an adjustment in the direction of the incident ray, sliding forward or backward, but keeping very accurately parallel to its former plane. The three adjustments of this mirror could be made with the wooden cover in position.

The paths being now approximately equal, the two images of the source of light or of some well-defined object placed in front of the condensing lens, were made to coincide, the telescope was now adjusted for distinct vision of the expected interference bands, and sodium light was substituted for white light, when the interference bands appeared. These were now made as clear as possible by adjusting the mirror $e_{\prime\prime}$; then white light was restored, the screw altering the length of path was very slowly moved (one turn of a screw of one hundred threads to the inch altering the path nearly 1000 wave-lengths) till the colored interference fringes reappeared in white light. These were now given a convenient width and position, and the apparatus was ready for observation.

5.



The observations were conducted as follows: Around the cast-iron trough were sixteen equidistant marks. The apparatus was revolved very slowly (one turn in six minutes) and after a few minutes the cross wire of the micrometer was set on the clearest of the interference fringes at the instant of passing one of the marks. The motion was so slow that this could be done readily and accurately. The reading of the screw-head on the micrometer was noted, and a very slight and gradual impulse was given to keep up the motion of the stone; on passing the second mark, the same process was repeated, and this was continued till the apparatus had completed six revolutions. It was found that by keeping the apparatus in slow uniform motion, the results were much more uniform and consistent than when the stone was brought to rest for every observation; for the effects of strains could be noted for at least half a minute after the stone came to rest, and during this time effects of change of temperature came into action.

The following tables give the means of the six readings; the first, for observations made near noon, the second, those near six o'clock in the evening. The readings are divisions of the screw-heads. The width of the fringes varied from 40 to 60 divisions, the mean value being near 50, so that one division

means 0·02 wave-length. The rotation in the observations at noon was contrary to, and in the evening observations, with, that of the hands of a watch.

NOON OBSERVATIONS.

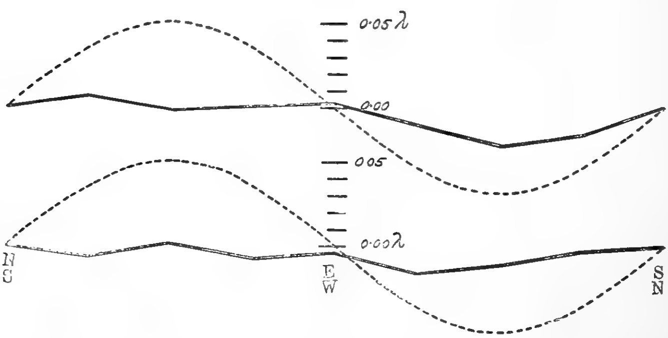
	16.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16·
July 8	44·7	44·0	43·5	39·7	35·2	34·7	34·3	32·5	28·2	26·2	23·8	23·2	20·3	18·7	17·5	16·8	13·7
July 9	57·4	57·3	58·2	59·2	58·7	60·2	60·8	62·0	61·5	63·3	65·8	67·3	69·7	70·7	73·0	70·2	72·2
July 11	27·3	23·5	22·0	19·3	19·2	19·3	18·7	18·8	16·2	14·3	13·3	12·8	13·3	12·3	10·2	7·3	6·5
Mean........	43·1	41·6	41·2	39·4	37·7	38·1	37·9	37·8	35·3	34·6	34·3	34·4	34·4	33·9	33·6	31·4	30·8
Mean in w. l.	·862	·832	·824	·788	·754	·762	·758	·756	·706	·692	·686	·688	·688	·678	·672	·628	·616
	·706	·692	·686	·688	·688	·678	·672	·628	·616								
Final mean.	·784	·762	·755	·738	·721	·720	·715	·692	·661								

P. M. OBSERVATIONS.

July 8	61·2	63·3	63·3	68·2	67·7	69·3	70·3	69·8	69·0	71·3	71·3	70·5	71·2	71·2	70·5	72·5	75·7
July 9	26·0	26·0	28·2	29·2	31·5	32·0	31·3	31·7	33·0	35·8	36·5	37·3	38·8	41·0	42·7	43·7	44·0
July 12	66·8	66·5	66·0	64·3	62·2	61·0	61·3	59·7	58·2	55·7	53·7	54·7	55·0	58·2	58·5	57·0	56·0
Mean	51·3	51·9	52·5	53·9	53·8	54·1	54·3	53·7	53·4	54·3	53·8	54·2	55·0	56·8	57·2	57·7	58·6
Mean in w. l.	1·026	1·038	1·050	1·078	1·076	1·082	1·086	1·074	1·068	1·086	1·076	1·084	1·100	1·136	1·144	1·154	1·172
	1·068	1·086	1·076	1·084	1·100	1·136	1·144	1·154	1·172								
Final mean.	1·047	1·062	1·063	1·081	1·088	1·109	1·115	1·114	1·120								

The results of the observations are expressed graphically in fig. 6. The upper is the curve for the observations at noon, and the lower that for the evening observations. The dotted curves represent *one-eighth* of the theoretical displacements. It seems fair to conclude from the figure that if there is any dis-

6.



placement due to the relative motion of the earth and the luminiferous ether, this cannot be much greater than 0·01 of the distance between the fringes.

Considering the motion of the earth in its orbit only, this

displacement should be $2D\frac{v^2}{V^2}=2D\times10^{-8}$. The distance D was about eleven meters, or 2×10^7 wave-lengths of yellow light; hence the displacement to be expected was 0·4 fringe. The actual displacement was certainly less than the twentieth part of this, and probably less than the fortieth part. But since the displacement is proportional to the square of the velocity, the relative velocity of the earth and the ether is probably less than one sixth the earth's orbital velocity, and certainly less than one-fourth.

In what precedes, only the orbital motion of the earth is considered. If this is combined with the motion of the solar system, concerning which but little is known with certainty, the result would have to be modified; and it is just possible that the resultant velocity at the time of the observations was small though the chances are much against it. The experiment will therefore be repeated at intervals of three months, and thus all uncertainty will be avoided.

It appears, from all that precedes, reasonably certain that if there be any relative motion between the earth and the luminiferous ether, it must be small; quite small enough entirely to refute Fresnel's explanation of aberration. Stokes has given a theory of aberration which assumes the ether at the earth's surface to be at rest with regard to the latter, and only requires in addition that the relative velocity have a potential; but Lorentz shows that these conditions are incompatible. Lorentz then proposes a modification which combines some ideas of Stokes and Fresnel, and assumes the existence of a potential, together with Fresnel's coefficient. If now it were legitimate to conclude from the present work that the ether is at rest with regard to the earth's surface, according to Lorentz there could not be a velocity potential, and his own theory also fails.

Supplement.

It is obvious from what has gone before that it would be hopeless to attempt to solve the question of the motion of the solar system by observations of optical phenomena *at the surface of the earth.* But it is not impossible that at even moderate distances above the level of the sea, at the top of an isolated mountain peak, for instance, the relative motion might be perceptible in an apparatus like that used in these experiments. Perhaps if the experiment should ever be tried in these circumstances, the cover should be of glass, or should be removed.

It may be worth while to notice another method for multiplying the square of the aberration sufficiently to bring it within the range of observation, which has presented itself during the

preparation of this paper. This is founded on the fact that reflection from surfaces in motion varies from the ordinary laws of reflection.

Let *ab* (fig. 1) be a plane wave falling on the mirror *mn* at an incidence of 45°. If the mirror is at rest, the wave front after reflection will be *ac.*

Now suppose the mirror to move in a direction which makes an angle α with its normal, with a velocity ω. Let V be the velocity of light in the ether supposed stationary, and let *cd* be the increase in the distance the light has to travel to reach *d.* In this time the mirror will have moved a distance $\frac{cd}{\sqrt{2}\cos\alpha}$.

We have $\frac{cd}{ad}=\frac{\omega\sqrt{2}\cos\alpha}{V}$ which put $=r$, and $\frac{ac}{ad}=1-r$.

In order to find the new wave front, draw the arc *fg* with *b* as a center and *ad* as radius; the tangent to this arc from *d* will be the new wave front, and the normal to the tangent from *b* will be the new direction. This will differ from the direction *ba* by the angle θ which it is required to find. From the equality of the triangles *adb* and *edb* it follows that $\theta=2\varphi$, $ab=ac$,

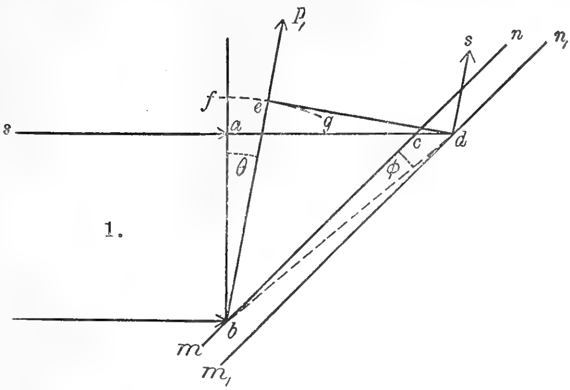
$$\tan adb=\tan\left(45^\circ-\frac{\theta}{2}\right)=\frac{1-\tan\frac{\theta}{2}}{1+\tan\frac{\theta}{2}}=\frac{ac}{ad}=1-r,$$

or neglecting terms of the order r^3,

$$\theta=r+\frac{r^2}{2}=\frac{\sqrt{2}\omega\cos\alpha}{V}+\frac{\omega^2}{V^2}\cos^2\alpha.$$

Now let the light fall on a parallel mirror facing the first, we should then have $\theta_{\prime}=\frac{-\sqrt{2}\omega\cos\alpha}{V}+\frac{\omega^2}{V^2}\cos^2\alpha$, and the total deviation would be $\theta+\theta_{\prime}=2\rho^2\cos^2\alpha$ where ρ is the angle of aberration, if only the orbital motion of the earth is considered. The maximum displacement obtained by revolving the whole apparatus through 90° would be $\Delta=2\rho^2=0{\cdot}004''$. With fifty such couples the displacement would be $0{\cdot}2''$. But astronomical observations in circumstances far less favorable than those in which these may be taken have been made to hundredths of a second; so that this new method bids fair to be at least as sensitive as the former.

The arrangement of apparatus might be as in fig. 2; *s* in the focus of the lens *a*, is a slit; *bb cc* are two glass mirrors optically plane and so silvered as to allow say one-twentieth of the light to pass through, and reflecting say ninety per cent. The intensity of the light falling on the observing telescope *df*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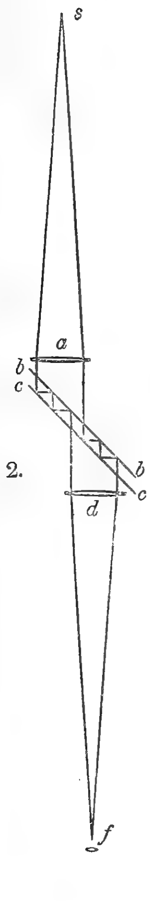
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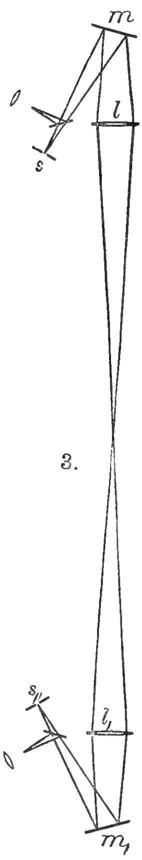
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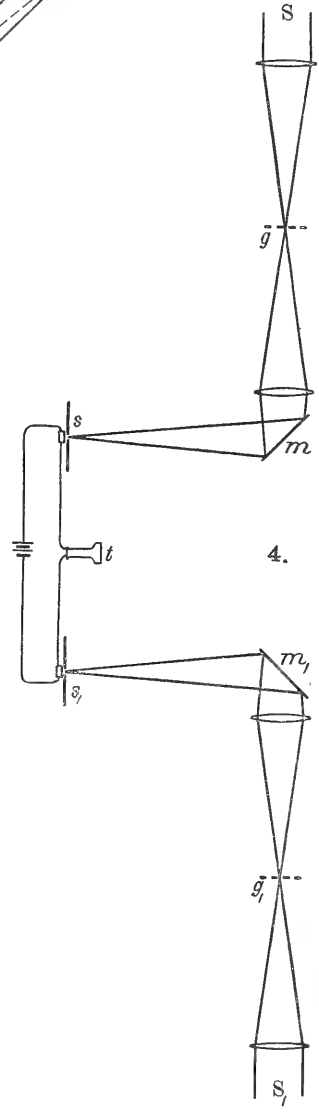
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4.

would be about one-millionth of the original intensity, so that if sunlight or the electric arc were used it could still be readily seen. The mirrors $bb_{\prime}$ and $cc_{\prime}$ would differ from parallelism sufficiently to separate the successive images. Finally, the apparatus need not be mounted so as to revolve, as the earth's rotation would be sufficient.

If it were possible to measure with sufficient accuracy the velocity of light without returning the ray to its starting point, the problem of measuring the first power of the relative velocity of the earth with respect to the ether would be solved. This may not be as hopeless as might appear at first sight, since the difficulties are entirely mechanical and may possibly be surmounted in the course of time.

For example, suppose (fig. 3) m and $m_{\prime}$ two mirrors revolving with equal velocity in opposite directions. It is evident that light from s will form a stationary image at $s_{\prime}$ and similarly light from $s_{\prime}$ will form a stationary image at s. If now the velocity of the mirrors be increased sufficiently, their phases still being exactly the same, both images will be deflected from s and $s_{\prime}$ in inverse proportion to the velocities of light in the two directions; or, if the two deflections are made equal, and the difference of phase of the mirrors be simultaneously measured, this will evidently be proportional to the difference of velocity in the two directions. The only real difficulty lies in this measurement. The following is perhaps a possible solution: $gg_{\prime}$ (fig. 4) are two gratings on which sunlight is concentrated. These are placed so that after falling on the revolving mirrors m and $m_{\prime}$, the light forms images of the gratings at s and $s_{\prime}$, two very sensitive selenium cells in circuit with a battery and a telephone. If everything be symmetrical, the sound in the telephone will be a maximum. If now one of the slits s be displaced through half the distance between the image of the grating bars, there will be silence. Suppose now that the two deflections having been made exactly equal, the slit is adjusted for silence. Then if the experiment be repeated when the earth's rotation has turned the whole apparatus through 180°, and the deflections are again made equal, there will no longer be silence, and the angular distance through which s must be moved to restore silence will measure the required difference in phase.

There remain three other methods, all astronomical, for attacking the problem of the motion of the solar system through space.

1. The telescopic observation of the proper motions of the stars. This has given us a highly probably determination of the direction of this motion, but only a guess as to its amount.

2. The spectroscopic observation of the motion of stars in the line of sight. This could furnish data for the relative

motions only, though it seems likely that by the immense improvements in the photography of stellar spectra, the information thus obtained will be far more accurate than any other.

3. Finally there remains the determination of the velocity of light by observations of the eclipses of Jupiter's satellites. If the improved photometric methods practiced at the Harvard observatory make it possible to observe these with sufficient accuracy, the difference in the results found for the velocity of light when Jupiter is nearest to and farthest from the line of motion will give, not merely the motion of the solar system with reference to the stars, but with reference to the luminiferous ether itself.

ART. XXXVII.—*On the Existence of Carbon in the Sun. Contributions from the Physical Laboratory of Harvard University;* by JOHN TROWBRIDGE and C. C. HUTCHINS.

[From the Proceedings of the American Academy of Arts and Sciences, vol. xxxiii.]

FROM the presence of absorption bands in the solar spectrum at high altitudes, Captain Abney has been led to believe in the existence of certain hydrocarbons between the earth and the sun; and Siemens's theory of the conservation of solar energy depends upon the supposed existence of carbon vapor in interplanetary space. It is not our purpose to discuss Abney's observations, or the truth of Siemens's hypothesis. We wish to call attention to the remarkable character of the carbon spectrum, formed by the voltaic arc in air between carbon terminals; and to draw attention to the evidence presented by the juxtaposed solar spectrum of the existence of carbon in the sun.

In our early experiments the carbon terminals between which the voltaic arc was formed were heated several hours, while a stream of chlorine gas was passed over them. This operation was not entirely successful in removing metallic impurities. Subsequently we discovered that the spectra of these impurities could be readily distinguished from the marked fluted carbon spectrum, and we therefore employed the ordinary compressed carbon sticks employed in electric lighting.

For our work the nicest adjustment of slit was necessary, in order that no displacement of spectrum lines could possibly occur when the carbon spectrum was photographed in juxtaposition with the solar spectrum. This was accomplished by the use of a slit, the jaws of which opened equally.

One of Rowland's concave gratings, of 21 feet 6 inches in curvature and 14,000 lines to the inch, was employed. In order to avoid any possible displacement of the photographic camera during the operation of photographing the carbon spectrum immediately below the solar spectrum, a drop shutter was arranged directly in front of the sensitive plate, the movement of which was independent of any movement of the camera. Preliminary experiments showed us the importance in this work of employing a spectroscope of great dispersion and of fine definition, giving also a normal spectrum. The use of a prism spectroscope would undoubtedly have masked the phenomena we have observed. For our purpose, therefore, Rowland's apparatus was peculiarly advantageous.

Our experiments lead us to conclude that there is positive evidence in the solar spectrum of the existence of carbon in the sun. Before giving an account of our experiments in detail, a few observations may not be considered out of place.

One who studies the solar spectrum by itself, and who has had no experience in the formation and observation of metallic spectra, is apt to regard the dark lines in the solar spectrum as fixed in character and condition. A line which is seen by one observer, and not by another, is generally regarded as a terrestrial line formed by absorption in the earth's atmosphere. Certain lines are well known to be due to the terrestrial absorption, as can be easily proved by their appearance when the sun is observed at sunset, when the rays of light have to penetrate a greater thickness of the earth's atmosphere than at midday. The shifting layers of vapor in the sun's atmosphere also may, in certain cases, obliterate or strengthen certain lines of metal. To understand this it is only necessary to extend the reasoning of the conservation of energy to the subject. It is a common lecture experiment to reverse the metallic lines by passing the rays of light produced by the vapor of the element through a layer of vapor colder than that of the source of the rays. The energy of the rays is thus absorbed in heating the colder layer. When the temperature of the vapor is increased, and becomes equal to that of the source, no reversal takes place. Thus, on the sun's surface the conditions for a reversal may be wanting at certain times, and faint lines may become bright. Their brightness may not be sufficient to affect the general illumination of the solar spectrum of which they form a part. Conditions may arise, moreover, in which the temperature of the reversing vapor may be called critical,—at such a temperature that the faint reversal is sufficient to extinguish the bright line of a metal without producing a well-defined dark line. At certain epochs, also, the temperature of the vapor of any element in the sun may be higher than at any other time; and certain

lines may thus appear which are wanting when the temperature falls. One is forced to these conclusions in observing the conditions under which the varying character of metallic spectra are produced. For instance, we have caused the rays from iron vapor to traverse a long and dense layer of iron vapor, and have observed that the strength of the lines and the number of reversals have been largely increased. In another experiment, the lower carbon of the electric lamp we employed occupied the center of an electro-magnet. This was accomplished by passing the carbon through a hollow iron cone, and surrounding the latter by layers of wire, through which the electrical current employed in generating the light passed. In this case the electric arc was spread out at right angles to the pole of the magnet, into a fan-like, intensely hot flame which roared loudly, and which rarefied, so to speak, the iron vapor between the carbon terminals. The strength of the lines and the number of reversals were diminished under this new condition.

Another phenomenon may happen. When an excess of the vapor of one metal floats over or is mixed with that of another, the lines of one metal are superimposed upon those of another in the solar spectrum, and the stronger spectrum of one element may easily obliterate the weaker spectrum of another. Thus we have succeeded in completely obliterating the fluted spectrum of carbon in the green and blue, by photographing upon it the spectrum of iron, of nickel, and cerium. A species of composite photograph was thus obtained. It is possible that in the future Galton's ingenious method of composite photography may be applied to the solar spectrum; and by a judicious selection of photographs of the elements, a composite photograph may be obtained which closely resemble portions of the solar spectrum, and will enable us to judge of the composition of the reversing layers of the sun.

To the varying conditions which we have thus outlined are due, we believe, the disappearance in the sun's spectrum of the marked fluted spectrum of carbon in the green and blue portions.

A careful examination of the fluted spectrum of carbon, however, with the juxtaposed solar spectrum, discloses a remarkable fact: while traces of obliteration of the evidence of carbon vapor are seen, yet the general character of the lines in the solar spectrum immediately juxtaposed with the fluted spectrum of carbon near H lead us to believe that there is unmistakable evidence of the existence of carbon vapor in the sun. When the arrangement of the fine lines of the spectrum of carbon is plotted as a curve, and that of the dark lines in the solar spectrum immediately above the carbon spectrum is

also plotted, the two curves have a remarkable similarity in character, running with a slight convexity toward one axis.

In the first fluting at wave-length 3883·7 within the limit of ten wave-lengths, over 28 of the spaces between the fine bright lines of the flutings coincide with dark lines immediately in juxtaposition in the solar spectrum. When we consider that the progressive arrangement of these lines is exactly the same both in the spectrum of carbon and that of the sun, we cannot consider that this coincidence is the result of chance. On examining the spectrum of carbon in the region near H still further, a remarkable number of coincidences of the spaces between the bright lines of the carbon spectrum with dark lines in the solar spectrum will be observed. We are led, therefore, to conclude that the fluted spectrum of carbon is an example of the reversal of the lines of a vapor in its own vapor. Fluted spectra occur at comparatively low temperatures. When carbon is ignited, we have at first a continuous spectrum. When the temperature increases and the carbon is volatilized, fluted spectra occur, which consist of interruptions of the continuous spectrum by fine line reversals occurring in harmonic order. The same phenomenon can be observed in the spectrum of iron lines: through the center of an iron line, when a sufficient amount of iron vapor surrounds the voltaic arc in which iron is volatilized, reversal lines are always seen. Now if the iron lines were arranged in regular order, the reversals would also be in like regular order, and would coincide with similar reversals in the solar spectrum. Assuming the conditions at the sun's surface to be the same as those we have in the voltaic arc, when carbon is volatilized, the character of the carbon spectrum should exactly agree with the character of the solar spectrum juxtaposed. This is found to be true to a remarkable degree in comparing portions of the solar spectrum with portions of the fluted spectrum of carbon beginning at wave-length 3883·7.

Our hypothesis leads us to conclude, that, at the point of the sun's atmosphere where the carbon is volatilized, so as to produce the peculiar arrangement of reversals observed, the temperature of the sun approximates to that of the voltaic arc.

ART. XXXVIII.—*History of the Changes in the Mt. Loa Craters;* by JAMES D. DANA. (With Plates II, III, IV.) Part I, KILAUEA.

[Continued from page 97, vol. xxxiv.]

SUPPLEMENT.

A JOURNEY of ten weeks (involving over ten thousand miles of travel) has enabled me to carry out the purpose expressed in my communication of August last. I have thus succeeded in supplementing the work of that one day at Kilauea out of five on Hawaii to which I was restricted in 1840, by one week at Kilauea out of two on Hawaii, besides having one week for the extinct crater of Haleakala and other parts of Maui, an island not before visited, and two for the island of Oahu.

The original objects of the trip were: (1), to examine the great lava-lake of Kilauea, Halema'uma'u, in its existing state of moderate activity; (2), to re-examine the rocks and walls of the crater; and (3), to compare the lines in the Wilkes map with the present outline of the crater, in order especially to remove doubts about the map before using it as a basis for historical conclusions.*

In this supplement I present such of the facts from my observations on the islands as belong to the *history* of Kilauea, reserving the rest about the crater for the "Summary and Conclusions" which will follow in another number, and the observations elsewhere for a later number. I introduce also a few facts from other sources. For the convenience of reference the map of the Government Survey is here reproduced (Plate II).

1. *Fissure ejections of* 1832 *and* 1868.—It is stated in early parts of this paper† that in 1832, and again in 1868, lavas were ejected through the depressed summit plain between Kilauea and Kilauea-iki. My observations enable me to state that Mr. Brigham's map, on page 89 of this volume, gives the position of the outflow of 1832, and the map of the Government Survey, Plate II, shows that of 1868. The lava of the latter stream has still a lustrous surface and little vegetation upon it, while the earlier has become weathered, and is much under shrubbery.

* I owe much of my success in the carrying out of my plans at the islands to Professor W. D. Alexander, Surveyor General of the Islands, Rev. Wm. C. Merritt, President of Oahu College, and Mr. J. S. Emerson, one of the assistants of the Government Survey, and am greatly indebted also to many others for kindnesses in various ways.

† Vol. xxxiii, p. 445 and this vol. p. 92.

The lavas of 1868 were ejected from a fissure nearly a hundred yards long, and flowed over the plain without descending into Kilauea, a portion of it covering part of the stream of 1832, as already stated. Many small trees standing in its course have now a rough cylindrical encasement of lava about their charred bases, which reaches to a height of from two to two and a half feet or more above the level of the flow, thus showing that the viscid stream, when reaching the trees on its way down the slope, had greater height of surface than afterward when the flow had passed by and its final level was attained.

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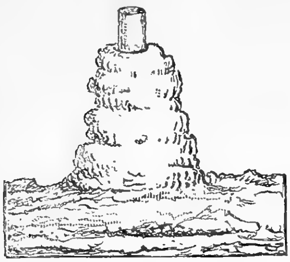


2. *Lower pit in* 1837.—The lower pit of 1832 had become very nearly obliterated, according to Mr. S. N. Castle, of Honolulu, by the latter part of August, 1837, as he informed me in August last. He found cones active in all parts of the crater.

3. *The "lower pit" of* 1868.—Mr. Nordhoff, in his "Northern California, Oregon and the Sandwich Islands,"* p. 45, says, speaking of the outbreak of Kilauea in 1868, "suddenly, one day, the greater part of the lava floor sank down or fell down a depth of about five hundred feet, to the level where we now walked. The wonderful tale was plain to us [March 3, 1873] as we examined the details on the spot. It was as though a top-heavy and dried-out pie-crust had fallen in at the middle, leaving a part of the circumference bent down but clinging at the outside of the dish." Mr. Nordhoff's statement as to the depth of the lower pit was evidently quoted, and is not independent testimony, but his comparison suggested by the sight of the place, sufficiently intelligible to an American, attests to the reality of the subsidence.

A letter from Mr. J. M. Lydgate, dated Laupahoehoe, Hawaii, August 10, 1887, contains the information that his map, reproduced on page 94 of this volume, was made after a survey in June of 1874. He also stated that the depth of the lower pit of 1868, was at that time, as nearly as he could now remember, "about thirty or forty feet where the trail crossed it."

4. *Level of the Great South Lake in January*, 1878.—Mr. C. J. Lyons, of the Government Survey Office, told me that on January 1, of 1878, he obtained, by means of a theodolite, 325 feet as the level of the lavas of Halema'uma'u below the datum mark at the Volcano House.

* 1874. New York and also London.

5. *Further testimony as to the eruption of* 1879.—The following testimony confirms the brief statement, on page 94, with regard to the fact of this eruption. It is from the hotel book of the Volcano House.

1878. July 20. "Halema'uma'u in a most active state." M. P. Robinson.—Sept. 20. "Very active." J. Mott Smith.—Nov. 24. "Very active; lava within a foot of top of bank."

1879. Jan. 8. "South Lake with lava 50 feet below the rim and boiling like water." Wm. Gardner.—March 19. "Large and bright lake."—April 15. "Light wonderful."

1879. April 21. "Bottom dropped out of crater." Wm. H. Lentz, of Honolulu.—Ap. 23. "Found the ——— thing extinct." G. Grœper.—Ap. 28. "Almost extinct; some vapors." Rev. A. O. Forbes, of Honolulu.—Ap. 29. "No fire at all." "Lake quite empty." J. Day.

1879. June 24. "Throwing up jets of lava; both lakes active; looks like a fountain of fire from the verandah of the Volcano House." Wm. H. Lentz.—July 2. "All traces of two lakes of July, 1878, obliterated, and instead an enormous single lake, which was quite active;" "lava thrown up 50 feet." Wm. Tregloan, of Honolulu.

The eruption was a discharge of the lavas of the Great Lake, as in that of March, 1886; and the lavas began to return in two months or sooner. Miss C. F. Gordon Cummings,* who was at the crater in the autumn of 1879, learned from others that the discharge took place on April 21st.

6. *Premonitions and effects of the eruption of March*, 1886, *in the vicinity of the Volcano House.*—The situation of the Volcano House is shown on plate II. It is within the great area of subsidence, northeast of Kilauea, where are many fault-plane precipices and numerous open fissures, many of the latter discharging freely hot air and steam, fumarole-like, and some of the deeper sending up also sulphurous acid gas. The large depressed area adjoining the house on the west is a true Solfatara, and the well-known extensive sulphur bank within it,—the only real sulphur bank about Kilauea at the present time—is hardly four hundred yards distant. A bathing house for vapor baths is near by, which is supplied with hot vapors from one of the fissures. The proprietor of the house, Mr. J. H. Maby, informed me that on the afternoon of the 6th of March, (Saturday) wishing to take a bath, he found at repeated visits the vapors at the bath-house too hot for it, and finally gave it up. At 9^h $30'$ of that evening a slight earthquake was felt, and at 9^h $45'$, three others, which made "thud-like sounds," or

* Fire Fountains of the Kingdom of Hawaii, 2 vols., 8vo, London, 1883.

"like the fall of a meal-bag on the floor." At 10^h the light over Halema'uma'u, before very brilliant, suddenly disappeared; the discharge had taken place. Through Sunday morning the escape of vapors from the fissures of the Solfatara region near the Volcano House went on, but it ceased entirely on Tuesday, and the stoppage continued through Wednesday and Thursday. Afterwards the discharge was gradually resumed.

The forty-one earthquakes which are reported as having occurred during the night, though not strong enough to shake down furniture in the house or crockery from shelves, felt to Mr. Maby as if the foundations of the house were giving way. The shocks have been attributed to the down-plungings of the walls of Halema'uma'u; but the intervening distance, 12,000 feet, is too great for such an effect; moreover, deep fissures were opened near by, along the road just east of the Volcano House, which are still steaming, and these suggest a sufficient cause.

The following facts are from the author's recent observations.

7. *Contrast in activity between the second week in November,* 1840, *and August* 11 *to* 18, 1887.—In November, 1840, the crater, over a very large interior region, including that of Halema'uma'u, was nearly a thousand feet in depth, and to the black ledge, or terrace, 650 feet. *Now*, as Messrs. Emerson and Dodge have reported,* the floor is everywhere less than 500 feet below the level of the Volcano House; the central part is but 400 to 360 feet; the Halema'uma'u border mostly under 340 feet; and, further, the floor slopes in all directions from Halema'uma'u to the base of the cliffs. The lava streams cover up all debris at the base. A few stones were observed imbedded in the lava that must have fallen during the flow before the lava had cooled.

In 1840, the Great South Lake—situated at the bottom of a southern prolongation of the lower pit nearly half a mile wide—was in fiery ebullition throughout, throwing up vertical lava-jets to a height of thirty feet or so over a surface of 1000 by 1500 feet; and it was so brilliant that at night the projecting angles and jetting points of the lofty black walls of Kilauea were lighted up throughout the whole circuit of the pit, and so hot as to forbid approach within 250 yards. *Now*, the Halema'uma'u basin, while a little over half a mile in mean diameter,* has at center a black and gray cone made of lava blocks and earth (as described by Mr. Dodge), sending forth vapors freely from apertures about it, but affording no signs of liquid lavas within; for even in a night view the clouds of vapors were

* This Journal, last volume, (pages 87, 98).

lighted up not over the cone, but east and west of it. Figure 2 is a view of the cone without its vapors, taken from the Vol-

2.

Cone in Halema'uma'u.

cano House; it is seen to rise out of an abrupt depression, which is that of Halema'uma'u. The narrow part of the depression to the left is the basin of the adjoining "New Lake." Plate III, representing the north end of the cone, with the bottom of the Halema'uma'u basin outside of it, illustrates its agglomerate nature. It is literally debris-made, and the debris is chiefly that from fallen walls, not the cinders or loose scoria derived from the ejections of a central vent. The plate shows also the character of the wall of Halema'uma'u, the stratification in the wall of Kilauea, and, above the latter, snow-capped Mt. Loa. The photograph from which the plate was engraved was taken in January last.

The only lake with active fires that was open to view in August last, was that on the west side of the cone; the more southern and the southeastern borders were swept by the wind-drifted vapors. The lake was but 150 by 175 feet in its diameters. It was mostly crusted over, but showed the red fires in a few long crossing lines (fissures), and in three to five open places, half way under the overhanging rock of the margin where the lavas were dashing up in spray and splashing noisily, with seemingly the liquidity of water. Now and then the fire places widened out toward the interior of the lake, breaking up the crust and consuming it by fusion; yet at no time was there a projection of the lavas in vertical jets in a free-boiling way; nor was it too hot to stand on the border of the lake if only the face were protected. Although relatively so quiet, the mobility of the brilliant splashing lavas made it an intensely interesting sight. Occasionally the red fissures widened by a fusing of the sides as the crust near by heaved, and the lavas flowed over the surface. It was evident from the cooled streams outside, that now and then more forcible movements take place, followed by outflows over the margin.

8. *The ordinary lava-stream, Pahoehoe of the Islanders.*—The ordinary Kilauea lava-stream made by overflowing or outflowing of the thoroughly fused lavas is remarkably smooth in surface. This is well seen in the small overflowings from the lava-lake, the lavas being so liquid that it may be dipped up

with a ladle or even a spoon.* But through one way and another it usually becomes uneven in general surface, wrinkled, billowy, hummocky, knobbed, fractured, and sometimes caved in or shoved out of place when fractured; and other rough features come from the adding of stream to stream. Plate IV shows something of the uneven character, but not the larger irregularities. Part of these rough features are owing directly or indirectly to crusting by surface-cooling, thinly or deeply, during the flow. Wrinkles, "billows" or domes, knobby and ridgy surfaces are depended on this condition, as well as the tunnel-like chambers and many of the shallower fractures. The fractures often lead to displacements of masses, and also to outflows of lava. In these outflows, the still liquid lava beneath the crust oozes out and fills the crack and so makes a seam, the immediate cooling at surface preventing a further flow; or the lavas pour out in larger volume and spread away in streamlets. Or the crust yields at a thin spot and the liquid stuff pushes out, but becomes at once stiffened and stopped by cooling and so makes projecting knobs of various sizes, shapes and lengths. Another source of uneven surface and cracks is the moisture beneath the flowing lavas of the crater, which is always present at greater or less depths since rain falls every other day or oftener.

The wrinkles and dome-shaped elevations or "billows" are remarked upon beyond.

The "pahoehoe" of Kilauea is of two kinds: (1) the ordinary lava of the mountain-side; and (2) that of the crater, distinguished by its separable scoriaceous glassy crust. The crust is a *crater*-feature, for I have not seen it on the lavas of the mountain outside. The crust, at the present time, is half an inch to two inches thick, and thickest in the vicinity of Halema'uma'u. As before described, it separates easily from the stony lava underneath; and this is so because the vesicles along the plane of junction are much larger than elsewhere.

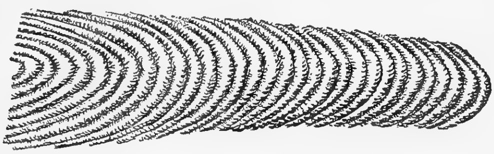
The stony lava beneath the glassy crust, making the body of the Kilauea streams, and many feet or yards thick is remarkably solid, having relatively few vesicles. Moreover, this light gray to black basalt contains commonly very little chrysolite (olivine). The most chrysolitic which I observed in Kilauea rocks was from one of the layers near the bottom of the precipice in Waldron's ledge, 100 feet or so above the level of the Kilauea floor. The stratified lavas of the *walls* of Kilauea, so far as examined, have the same compact stony character as those of the bottom, the same sparing distribution of air-vesicles. Some of the kinds, of light gray color, are almost wholly free from vesicles. But while the upper part of a layer in the walls is sometimes scoriaceous, it is never covered with a glassy crust.

* I have a spoon filled with lava that was dipped up by Mr. Coan.

The lavas exuded through the crust from the liquid mass below, above alluded to as making seams, streamlets and knobby surfaces, are covered sometimes with separable scoriaceous glassy crust, though commonly having a solid glassy exterior half an inch or so thick.

9. *The wrinkled surfaces or tapestry-like folds of the flowing lavas.*—While looking at the small lava lake, the making of the tapestry-like folds, so common a fluidal feature of the lava-streams of Hawaii, was well exemplified. A stream of lava came out from beneath the cone and flowed obliquely across the lake, making the folds or wrinkles by its onward movement in the thin crust which surface cooling had produced; and the wrinkles were convex down-stream because of the greater velocity at centre. The accompanying figure repre-

3.



sents, reduced, a small portion of the stream. At one time a lateral shove took place along one of the fissures in the crust of the lake, and the next moment the margin was rolled over into a long fold or wrinkle, and then by the more rapid movement of the middle portion, a large part of the fold became twisted into a rope. Thus fold may follow fold, and make a group or series of rope-like folds; and tapestry wrinkles become rope-like by a similar method.

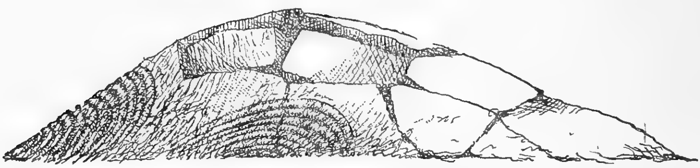
The tapestry-like folds of the surface of streams are sometimes folds simply in the scoria-crust; but they commonly consist of the more solid lava also, or of that alone where the scoria-crust is absent. This rope-making goes on over parts of outflowing lava streams. Sometimes, in connection with the making of the long ropes, the crust, where thin, becomes bent upward so as to have a long empty space a foot or two deep beneath the brittle cover. It is a trap for the incautious traveler, but it usually startles without injuring, yet serves to point a paragraph about the dangers of the crater.

On Plate IV, which represents the general aspect of the floor of Kilauea (and of many lava flows elsewhere) there are examples of the tapestry-like folds, and some of the small folds are twisted rope-like.

10. *Dome-shaped bulgings of lava-streams made sometimes, if not generally, after the stream has flowed on.*—Such bulgings, the

"billows" or "hummocks," in part, of some describers, are common here and there over a stream and often have a height of fifteen to twenty feet. I have attributed them, in my Exploring Expedition Report, to steam made from moisture underneath. This view is sustained by the actual arching of the stratum, often seen in a cross-section, and also by the cavity or cavities within and the broken or fallen-in top. Some seem to have been further crushed by the push of a subsequent lava flow.

4.



The sulphur vapors may also aid in making these dome-shaped elevations. And when so, the space below may have, as the facts show, the roof covered with a crust and stalactites of glauber salts, or with a thin crust of gypsum; the vapors having contributed material for the sulphuric acid, and the labradorite of the lavas, the soda or lime.

In many places evidence was plain that bulging had taken place after the flow of the lava-stream though before complete consolidation. This evidence was afforded by the tapestry folds on the bulged surface, they being upside down; that is, the folds were often convex upward instead of downward, as in the figure. The tapestry folds indicate the direction of movement; and, when thus upside down, they prove that they had been turned out of their original position.

11. *Flames from the lava-lake.*—The party which made a night visit to the small lava-lake in Halema'uma'u, the evening before we left the place, saw flames, similar in all respects to those reported by Mr. Brigham.* They were seen to rise where heavings and breakings of the lava-crust took place, and not where the fires were most active. The flames were one to three feet in height. They were very pale in color and slightly greenish rather than bluish. I cannot claim myself to have seen the flames—the rains of the evening, and a cold from a thorough wetting the day before, having prevented my joining the party. But critical observers were of the number—as Mr. Emerson of the Government Survey, President Merritt of Oahu College, Rev. S. E. Bishop and others, and the testimony was unanimous.

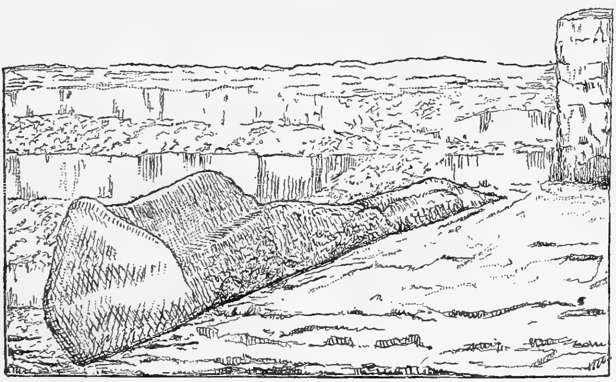
* This volume, pages 91, 95.

12. *Floating Island of* 1882 *to* 1886, *now stranded.*—Mr. Emerson speaks of the stranded floating island of New Lake as over sixty feet high, and describes well its surroundings.* I found, from an early photograph, that not long after it began its floating career it had the form shown in the following figure, as if it were a portion of a solidified lava-stream, either taken

5.

from the sides of the lake, where undermining by the dashing and fusing lavas might have separated it, or more probably derived from depths below and floated upward by the rising lavas. An examination of the stranded island showed that it consisted of the ordinary Kilauea lava, not much vesiculated, but enough to enable it easily to float. Further, it indicated great change in form since its first appearance. It lies on the bottom of the emptied lake-basin, as seen in the following figure (taken from a photograph). Two other photographs

6.



which I obtained at Honolulu, show intermediate forms, but they do not differ greatly from figure 5 above. The change in form might have come both from the projection over it of liquid lavas, and from erosion of its sides by the fusing heat. It is not known how much of it was beneath the surface of the lava; but the reader may perhaps satisfy himself on this point.

13. *The fissured borders of Kilauea.*—Besides the great fissures of the northern border of the crater, near the path of

* This Journal, xxxiii, 91, 1886.

descent with the subsided belts between, and the many fissures of the Solfatara depression just back, others occur farther north and east, to a wall, about forty feet high, which is evidently a fault wall. This wall is about 2000 feet from Kilauea at the northwest corner, and diverges eastward to about 5000 feet, and then bends around southward so as to embrace Kilauea-iki within the large northern border region of fissures and subsidence.

Deep and wide rents extend also along the whole western border of Kilauea, generally two or more together; and near the highest station, Uwekahuna, there are six of them parallel to one another. South of this station, between it and the southwest angle of the crater, the fissures are continued over a large depressed border 500 to 1,500 feet wide, lying between a precipitous ridge—fault-plane—on the west and the crater. North of Uwekahuna the evidences of subsidence now visible are small; but south of it the surface has different terrace levels, showing great and various sinkings of the surface. Almost in front of Uwekahuna, bordering the Kilauea wall, there is a surface, 200 to 298 feet below the level of this station, according to the Government maps, which is plainly, as seen from below, a result of subsidence; and various other terrace-levels exist farther south. On the east side of Kilauea, also, there are fissures parallel to the walls; and large depressed areas exist between Kilauea and the two adjoining craters. Fissures extend northward to the east of Kilauea-iki, as noticed by the Wilkes expedition in 1840, and new openings there, near the Keauhou road, were reported as opened in March, 1886, at the time of the eruption.

The wall on the northeast side of Kilauea, near the path of descent, called Waldron's ledge (after a purser in the Wilkes expedition) is one of the highest and most stable parts of the walls, being but eleven and a half feet below the level of the Volcano House datum. It is a bare-faced, vertical precipice, showing stratified lavas to the top. Like Uwekahuna, it seems to be an exception to border instability. But it stands on the brink of the most unstable region—that of the north side. In a walk along the base of the precipice I found a fresh uncovering of the rock at bottom for a height of two to three inches, showing that a recent sinking adjoining it had taken place, or that one was then in progress.

This border belt of fissures and subsidences, if reckoned as part of the Kilauea fire-region, or region of disturbance, adds 5000 feet to the length of the region, and nearly doubles the width across the northern half.

There are long fissures also, over the region southwest of the crater, some of which were reported by the Mission Deputa-

tion of 1825. It is an interesting and important fact that while the fissures about the northeast end of Kilauea are *concentric* with the outline of the crater (Kilauea-iki being included with it), those at the south end are nearly all *longitudinal*, or in the direction of the longer diameter, southwestward. Moreover, as is well known, they extend on for twelve to fifteen miles to the southwest. They are very numerous, more so than is shown on any map or recorded in any description; and some are very deep in places, giving off hot air, steam and sulphurous acid fumes in great volume. While some of them date from 1868, and others from 1886,* still others existed back of all records.

The subsidence that has gone on over this southwestern fissured area has not left any satisfactory evidence of its amount. We know only, that (as the Government map teaches) the surface is about 280 feet below the level of the Volcano House and 395 below that of the Uwekahuna station.

14. *Volcanic sand, stones and scoria, covering all the borders of Kilauea, from an eruption about the year* 1789.—The account of the eruption of 1789, gathered from the natives by the Rev. I. Dibble and published in his "History of the Sandwich Islands"† (1843), mentions that for two nights there were eruptions with ejections of "stones and cinders;" soon followed the rising of a dense, dark cloud from the crater, with thundering and lightning, and then "an immense volume of sand and cinders which were thrown to a great height, and came down in a destructive shower for many miles around."

The "sand and cinders" of this eruption (the latter usually called on the island *pumice*,‡ on account of its extreme lightness, and first mentioned by Ellis, who says "light as a sponge") are well known to cover an area of "many miles" to the southwest of the crater; but the accounts of the region have said nothing about the stones until the publication of Professor C. H. Hitchcock in Science of February last, after his visit to the crater in the summer of 1886. He there reports that:

"Standing at Keanakakoi, one sees to the southwest and south a stretch of volcanic sand and dèbris fully equal in dimensions to Kilauea itself. On examining more closely the material called 'gravel' on the map, it was seen to consist of material

* Mr. Emerson distinguishes the two sets in his paper in the last volume of this Journal. An exact mapping and numbering of all the fissures, as well as determination of levels, about the Kilauea border would be a very important step toward a correct reading of the future history.

† The facts which Mr. Dibble publishes are cited in my Expl. Exped. Report, on page 183.

‡ Pumice is the scoria of a trachytic or some orthoclase-bearing lava, with the vesicles linear.

ejected from the volcano, and numerous lava-bombs were picked up. Ashes also cover the country to the south and southwest over the Kau desert for several miles."

But it is still not appreciated that Mr. Dibble's words "many miles around" are true if made to include the whole circuit of Kilauea, even the vicinity of the Volcano House, and that the projection of stones preceded that of the light scoria ("pumice"), as Mr. Dibble's account says; yet was itself preceded by a great shower of volcanic ashes or sand. The facts show, moreover, that the stones are in great numbers and of large size to the west and northwest of the crater. The deposit has its maximum thickness over a large area south and southwest of the crater, where it is twenty-five to thirty feet thick and extends ten miles or more away. It is well exposed to view along the fissures. The lower twenty to twenty-five feet of the deposit consist of yellowish brown beds of tufa, the material very fine volcanic sand and hardly consolidated. Above the tufa are two to three feet of a coarse conglomerate consisting chiefly of stones; and above this stratum, a bed twelve to sixteen inches thick of closely packed brownish sponge-like scoria ("pumice"), in pieces half an inch across to two or three inches.

This sponge-like scoria contains the least possible amount of solid matter, being about ninety-eight and one-third per cent air, the rest glass; for the small round cells have no walls except a few slender threads, and it is about as light as a dry sponge. On account of its lightness it is easily carried off by winds as well as the sleepiest of waters, and hence the bed is often left in patches.

The ejected stones vary in size up to several cubic feet. Those of one to two cubic feet are common, many are 20 to 30, and one seen on the west side measured 100 cubic feet and must have weighed over eight tons. Part are ordinary volcanic scoria; but the most of them consist of the more solid basalt sparingly vesicular; and many of the larger are of a light-gray kind very slightly vesicular or hardly at all so, only slightly chrysolitic, and frequently having on the worn exterior a faint banded appearance from alternating variations in compactness of texture. Another kind varies in color from faintly reddish to gray, is more or less vesicular, and contains a large amount of chrysolite—suggesting the nature of a bomb, though not having an exterior shell.*

Going from the southwest border northward and approaching the highest point on the west side, the Uwekahuna station of the survey, the deposit becomes thinner, but retains well its

* The rocks collected on Hawaii have not yet arrived and hence only general descriptions are here given.

characteristics. North of this station the thickness becomes ten feet and less. At the Volcano House it is six feet or more. It may be seen in front of the house at the first descent, where it includes, at bottom, a bed of pebbles; upon this, six to eight inches of the spongy scoria ("pumice"); then another pebbly layer and some fine tufa. It occurs also just north of the Volcano House garden and may be found in traces elsewhere about the north border.

From the south border of the crater the formation extends around by the east side not only to Keanakakoi,* but to the Kilauea-iki depression, thinning northward as on the west side, but having the same characteristics, as observed in the spongy scoria, the great numbers of large stones and the kinds of rock constituting them. But the stones, though many and large, are of somewhat less size than to the west and southwest, and the "pumice" to the northward on this windward side of the crater is in thin widely scattered patches. The tongue of land extending from that side toward the south end of Halema'uma'u, with the words over it on the map "gravel and boulders," owes its gravel and many bowlders to the same source, as Professor Hitchcock implies. The low plain between Kilauea-iki and Kilauea fails of it; but this is owing to recent lava out-flows over the surface. The deep soil and earth farther east over a region crossed by the north and south carriage road by which we made the ascent to the crater, bearing tree-ferns, etc., in luxuriance, is probably an eastern portion of the tufa formation.

The greatness and violence of the eruption cannot be doubted. Its distribution all around Kilauea seems to show that the whole bottom of the pit was in action; yet the southern, as usual, most intensely so. The heavy compact rock of the stones and the size of many of them indicate that the more deep-seated rocks along the conduit of the volcano were torn off by the furiously ascending lavas. It was a *projectile* eruption of Kilauea such as has not been known in more recent times.

I looked along the walls of Kilauea to ascertain whether there was evidence of earlier eruptions of the kind, but found

* The name *Keanakakoi* or Keana-ka-koi, applied on the Hawaiian Government map to the small crater east of the southern half of Kilauea, signifies, as I was informed by an intelligent native, the *chipping-stone pit*, and refers to the fact that formerly a very compact grayish lava was obtained at its bottom and used there for the manufacture of stone implements. No such stone or manufacture has ever existed at Kilauea-iki. This appears to settle the question as to the correct application of the latter name raised by Mr. Brigham. The crater has now a bottom of very smooth recent lava, which our guide stated had been ejected 8 or 10 years back; which suggests that the ejection may have occurred at the time of the eruption of 1879.

no such beds of tufa or conglomerate, and no tufa or sand beds of any kind intervening between the beds of lava constituting them. There are fresh-looking lava-streams over the slopes of Kilauea southwest of the crater, but none appeared along the route to Punaluu of more recent date than the cinder deposit.

15. *The aa lava streams.*—The *aa* areas, looking like ploughed-up lava streams on a majestic scale, occur in the course of outflows of both Kilauea and Mount Loa, and a small area of the kind now exists (see map) in the floor of Kilauea. Several of them were seen on the way up from Keauhou to Kilauea; one about ten miles from Kilauea in Kapapala, near the road to Punaluu, three near Punaluu on the southern border of Hawaii, and one on the lava stream of 1881, within six miles of Hilo. The coarsest and most characteristic of them are those near Punaluu; and that near Hilo has special interest. In crossing Hawaii in 1840 I was over others between Punaluu and Kaulanamauna. My new study of them has led me to a change of opinion as to their mode of origin and to an explanation not yet on record. The description which follows will give others an opportunity to speculate about them.

An *aa* or *arate* lava stream consists of detached masses of lava, as far as is visible from the outside. The masses are of

7.

very irregular shapes, and confusedly piled up to nearly a common level, although covering often areas many miles long and half a mile to a mile or more wide. The size of the masses in the coarser kind varies from a few inches across to several yards. The rock constituting the body of the mass is the ordinary solid lava, usually little vesiculated, not the scoriaceous; but the exterior surface is roughly cavernous and horridly jagged, with projections often a foot or more long that are bristled all over with points and angles. In some cases ragged spaces ex-

tend along planes through the large masses, like those of the exterior. But in these as in other parts, it is evident that the agency was tearing and up-ploughing, and cavity-making in its action, and not vesiculating. At one place great slab-like masses of very compact rock, 20 feet or more long, stood vertically together, each about 8 feet high and 3 to 10 inches thick, with a curving over at top, somewhat like gigantic shavings. Ellis, in the "Journal" of the Hawaiian tour of the Mission deputation in 1825, appears to describe similar occurrences over the *aa* fields in the following words:

"Slabs of lava from 9 to 12 inches thick and from 4 to 20 or 30 feet in diameter, were frequently piled up edgewise or stood leaning against several others in a similar manner. Some of them were 6, 10, or 12 feet above the general surface."

These piles of jagged rocks have usually a height of 25 to 40 feet above the level of the adjoining smooth-surfaced stream, owing this height evidently to the large spaces among the blocks.

The above figure represents the features of such a stream. The title of such piles of blocks to the name of a stream would not be admitted were it not proved that they are formed during the progress of a lava-flow; that a lava-stream may change from the smooth-flowing or (pahoehoe) condition to the *aa*, and back again to the smooth-flowing; and that the same vent may give out at one and the same time, a smooth-flowing stream in one direction, and an *aa* stream in another. The Mt. Loa stream of 1880–'81, is mostly a smooth-surfaced stream; but over part of it, within six miles of Hilo (where I went under the guidance of Rev. E. P. Baker, a close student of the Hawaiian volcanoes), the pahoehoe stream changed for a few hundred yards to *aa*, with evidences of transition between them. Further, Mr. Furneaux, an artist, informed me, in his studio at Honolulu, that he was at the head of the flow of 1880, on Mauna Loa, when it was in progress; that one of the three streams which was then flowing from the vent—that going southeastward—was of the *aa* kind, while the other two were smooth-flowing or pahoehoe; that he saw the *aa* stream very gradually advancing, the sides apparently motionless, but about the front, now and then a block tumbling down from above; and the blocks toward the foot at intervals making a shove onward, and rather gaining on the bottom portion where there was impeding friction; and he noticed a red heat between some of the blocks in the front portion. He had in his studio a painting of the scene.

In some *aa* streams, however--probably the thinner streams—the masses are much smaller and more scoria-like than above

described; and these graduate into broken scoriaceous lava-flows.

In two of the *aa* streams near Punaluu the lava is but slightly chrysolitic; in a third somewhat more recent stream, situated not a mile farther west, the lava is very abundantly chrysolitic. All the facts appear to show that there is no connection between kind of rock and kind of flow.

16. *The enormous bomb-like masses of some aa streams.*—The bombs, as they might be called, of the *aa* streams are, inside and out, in striking contrast with the other masses. Many of them occur in the Kapapala stream, and also in those near Punaluu. They are smoothish exteriorly, more or less rounded and bowlder-like; and they vary in size from a mean diameter of a few inches to ten feet and more. One of them is represented in the *aa* picture at the top to the right (p. 362).

Some of these bombs consist outside of a crust, four to six inches thick, of hard grayish, slightly vesicular basalt, and *inside* of fragments of reddish or grayish scoria, the shell being packed full of the scoria fragments. In others similar, the scoria was partly rolled up. Some of them consisted of concentric shells, hard and scoriaceous shells alternating with one another. One had a nucleus of scoria 18 inches in diameter; and around this, successively, a stoney shell of 3 inches; a scoriaceous layer of 1 to 2 inches; a stoney shell of 4 to 5 inches, and then, outside, a rough lava shell 6 inches thick. One of large size, broken open on one side, had had its inside filling of scoria worked out by the natives, and so made into a small cave.

A common size is three to five feet in diameter: but one enormous bomb, in the *aa* field west of Punaluu, measured $24 \times 12 \times 9$ feet in its extreme dimensions, and contained at east 1,000 cubic feet. Enough of its hard outer shell was pealed off to ascertain that the second layer was much vesicular or scoriaceous, and the next layer inside, hard basalt again.

These bombs lie in the midst of the other blocks of the *aa* stream, proving that all had a common origin, and *that they are not projected bombs*, and hence, properly, not bombs at all.*

The further discussion of the phenomena of Kilauea is left for the "Summary and Conclusions."

[To be continued.]

* The word *a-a* is pronounced as if written *ah-ah*, the vowels in all Hawaiian words having the Italian sounds; *au* has the sound of *ow* in English. Kilauea has an accent on the *e*, and Haleakala on the *a* before the *k*. *Pahoehoe* means smooth and shining, and its use is not confined to lava.

ART. XXXIX.—*Is there a Huronian Group?* by R. D. IRVING.

[Continued from page 263.]

VI. North of the northern limit of the Animiké beds, slaty and schistose rocks form a belt which extends from Vermillion Lake in an easterly and north of east direction to the national boundary line in the vicinity of Knife and Saganaga lakes, a distance of some 60 miles. To the west of Vermillion Lake this belt has been traced for some miles, but is soon lost underneath the heavy glacial accumulations of that region. To the north the schists become involved with granitic and gneissic rocks. A similar area of granite and gneiss bounds the schistose belt on the south, over much of the distance, and here also are seen again the intricate intersections of the schistose rocks by the granite. After reaching a point some thirty miles east of Vermillion Lake, however, the great flat-lying mass of gabbro which lies at the base of the Keweenaw Series of that region overlaps and conceals this granite, the overlap extending over to the schistose belt itself. Another granite area lies directly athwart the course of the schists in the vicinity of Saganaga Lake, although a portion of the schist belt apparently continues farther to the northeastward into Canada along the northwestern side of this granite.

Folding and the production of a schistose structure by lateral pressure seem to have been pushed to the very last extreme among the rocks of this slate and schist belt, the dips within which are generally close to vertical, although here and there among some of the fragmental rocks of the belt, close crumplings may be traced with their sharp anticlinal and synclinal bends. The secondary schistose structure, with its accompanying metasomatic changes has been developed to the highest degree among the rocks of eruptive as well as among those of sedimentary origin. The common structural directions of all the rocks of the belt, as to both strike and dip and the generally prevailing schistose structure, suggest at first the conclusion that all of the schists of the belt are part of one formation; or, if of two formations, that the distinction between the two is no longer recognizable.

A closer study, however, serves to render such a conclusion less evident; and shows that we have among the rocks of the belt two types, in one of which the crystalline structure is complete, and in which there is little or none of an original fragmental texture, while in the other the fragmental texture is still distinct and the alteration has progressed to a smaller degree. Associated with the latter, slaty rather than schistose,

rocks are found great developments of jaspery and cherty ferruginous schists, whose identity as to nature and origin with the ferruginous schists of the iron-bearing formations of the south shore of Lake Superior, and of the Animiké formation of the north shore, seems complete. This identity, taken together with the close similarity of some of the fragmental rocks of the Vermillion Lake band to the fragmental rocks of the Animiké and of the south shore iron-bearing formations, and with the further similarity that obtains between the more distinctly crystalline schists of the Vermillion Lake band and those of the older or gneissic formation of the south shore of Lake Superior, suggests to us that we have here again to do with a separation into an older and a newer schistose formation. This suggestion is deepened into conviction when we further consider the fact that the supposed older one of the two groups of schists in the Vermillion Lake belt is intricately penetrated by the granites of the great areas north and south of the belt, while the same granites, where they come in contact with the supposed newer schists, have yielded to them a profusion of fragmental material, among which fragments are many derived from the supposed older schists themselves.

The appearance is, then, that the conditions obtaining in the Vermillion Lake belt are analogous to those which present themselves in the Menominee region, already briefly described, with the difference that the folding and schistose structure due to lateral pressure have been pushed to an extreme far greater in the former region.

VII. The several regions thus considered furnish us then with a graded series as to the structural relations of the older and newer rocks in each case. The *Animiké rocks* lie upon the older formation with only a slight inclination, and without folds. The *Penokee iron-bearing series*, though still unfolded, lies with a steep northern dip against a wall of the older granite-invaded schists. Next in order comes the case of the unconformity on the north shore of Lake Huron, where the *typical Huronian series* is gently bowed, but is without true schistose structure. In the case of the unconformity of the *Marquette region*, the upper group is crumpled between walls of the older schists, at times even having the folds overturned, with frequent developments of slaty cleavage; but still having the folds in the main open, and presenting a true schistose structure only rarely. In all of these cases—least distinctly of course in the last case—the distinctness of the two formations concerned is to be made out in part from the visibly discordant positions of the rocks of the two series. But when we proceed to the next case on the list, that of the *Menominee region*, such discordances are no

longer distinct, the close folding having brought the strati-form members of both groups to too great a uniformity of inclination. Finally, in the *Vermillion Lake region* the extreme pressure to which the rocks have been subjected has not only brought about a general community of inclination between the rocks of the two groups, but has developed in the lower group, and among the eruptives of the upper group, so complete a schistose structure as to render the separation of the two series often exceedingly difficult. Nevertheless, that the two groups are there actually represented the facts above presented seem to me clearly to demonstrate; while such a state of affairs as there obtains is certainly no theoretical impossibility on the hypothesis that these schists include two entirely distinct series of rocks. Imagine, for instance, the region of the Alps of southern Europe planed off by denudation to a level surface. Here Archæan crystalline schists and various fossiliferous formations are intricately folded together; and the appearances resulting from such a planing off would not be so far different from those obtaining in those portions of the Lake Superior region, where Archæan schists and newer detrital rocks are folded together, save that the newer formations would now be fossiliferous.

There must be cases, however, where it will long remain very difficult, if not impossible, to separate the Huronian from older schists, or to determine if any Huronian be present. This I suspect will be the case with some of the Canadian belts north and northeast of Lake Superior, which have been called Huronian. A large part of the schists of these belts are plainly *not* Huronian; but it remains to be seen whether any of the belts contain any true Huronian, and whether there may not be some further division possible of the pre-Huronian schists; a view maintained vigorously by Mr. Lawson, of the Canadian Survey. As to this I do not care to express, now, any very definite opinion. However, it seems plain that no such facts as those here presented to substantiate the complete separation that obtains between the Huronian and the pre-Huronian rocks have been yet advanced to establish a separability of the latter rocks themselves.

Throughout the region then which stretches from the north shore of Lake Huron to the Mississippi River, we find evidence of the existence of this same discordance between the Huronian, and the older basement rocks—a discordance due to one and the same orographic disturbance. Bearing in mind the discordance between the Huronian and the overlying Keweenaw series, and that between the Keweenaw series and Potsdam sandstone, we reach the conclusion that throughout this great region the following succession obtains, in ascending order:

(1.) The great *basement complex*, of crystalline schists, gneiss and granite, as to whose further divisibility or non-divisibility no opinion is now expressed. Above this basement, but separated from it by a great structural hiatus, follows:

(2). The *Huronian Group*, mainly of detrital rocks; which is followed in turn, but after a severe structural break, by

(3). The *Keweenaw Group* of interleaved detrital and eruptive beds, which is also entitled to the group rank. Finally, upon the eroded edges of this series follows

(4). The *Potsdam* or Upper Cambrian sandstone.

VIII. Thus far I have directed your attention only to the region between the north shore of Lake Huron and the upper Mississippi River—a region which we may conveniently call the Lake Superior Geological Province. But geologists have often made correlations of the rocks of other and remote regions with the type Huronian, and this not only for various portions of North America, but of other continents as well. Such correlations have been made chiefly, often exclusively, on the basis of a lithological similarity to the original or type series, and should therefore be received with the very gravest doubt; but to make the matter worse the lithological comparison has been with a standard *which does not exist in the type area*, and which, where anything like it does appear in the neighboring regions, is plainly pre-Huronian, i. e., is part of the great basement complex.

Correlations with the type Huronian may be received with more confidence perhaps, if for regions not too remote from the type area, when based on a parallelization of unconformities above and below the type series. Such unconformities are plainly the result of an intervention of mountain-making disturbances whose influences must generally have been widespread. Thus a succession similar to that of the Lake Superior region, and with similar discordances, obtains beneath the equivalent of the Potsdam sandstone in the Colorado Cañon; and probably also in Central Texas. In Newfoundland again, lying unconformably beneath the lowest known fossiliferous Cambrian horizons, are two mutually discordant series, the upper one of which is detrital, and the lower crystalline and gneissic. The use of such a method of correlation, however, is not advocated as being of value in inter-continental comparisons, or even in inter-regional ones, when the basins compared are too remote from one another; though it may be said that it could hardly give much less satisfactory results than have at times been yielded by the paleontological method.

But while we cannot with confidence correlate the Huronian or Keweenawan of the Lake Superior region with any particu-

lar pre-Cambrian series outside of that geological province, we can confidently enough, I think, correlate the geological interval which holds these Lake Superior formations with that which intervenes the world over between the Cambrian and the great basement of genuine crystalline rocks, and which in several regions includes great groups—sometimes one, sometimes more—of fragmental sedimentary strata. The progress of geological discovery has been a downward one, and we may look for the discovery of more fragmental groups than these, and, I think, for the discovery of new faunæ In any case, whether our discoveries in this direction are at an end or not, some term—at least provisional in its application—covering the great interval between the Cambrian and the Archæan, and the clastic groups which have been or may be found lying in this interval, would not only be a convenient addition to geological nomenclature, but would express a great truth which the taxonomical system now generally in use entirely ignores.

IX. In the foregoing pages I have shown that the Huronian series is traceable throughout the Lake Superior Province, and have presented a summary of facts which, as it seems to me, establish its clastic and sedimentary nature, its great volume, and its structural and chronological separateness from all other rock groups. I may now turn back once more to the quotation which serves as the text of this essay and see how far the definition of a group there given is satisfied in the case of the Huronian series; and, if there is any failure to satisfy this definition in full, whether such failure should be allowed to exclude this immense volume of strata from the group column, and to compel the ignoring in geological chronology of the immense lapse of time to which it must correspond.

Analyzing the definition referred to, we find that it includes the following distinct requirements; whose order, however, for convenience of reference, I change from that given in the quotation itself:—(1) All clastic formations, known to be such, must be included within some group or other; (2) the group is made up of sedimentary (mainly clastic) strata; (3) it includes subordinate members genetically separate from one another; that is, is made up of *formations;* (4) it has a volume comparable with that of other recognized groups, such as the Cambrian, Silurian, Devonian, etc.; (5) it is presumably world-wide in distribution, being recognizable in various countries; (6) it is defined mainly by paleontology, or "is admitted by all geologists for motives in part arbitrary."

The first of these conditions plainly compels us to place the Huronian in some one of the already recognized groups, or to make a new group for it, of which alternatives it has already

been seen that we can take only the latter. It has also already been abundantly shown that the second, third and fourth requirements are fully met in the case of the Huronian. As to the fifth, it is to be said that a thickness of 18,000 feet of sedimentary strata, extending, as the Lake Superior Huronian does—or did before erosion—over an area of 800 by 400 miles, and in all probability over an area as large again as this, certainly has "presumptively" its exact chronological equivalent in other geological basins. That it has been recognized in other countries cannot be said. Rocks of fragmental origin which are with sufficient probability, in part at least, the equivalents of the type Huronian have been recognized in different countries, and on different continents, between the Cambrian base and the Archæan schists; but all that we can now say with regard to them is that they belong to the same general geological interval with the Lake Superior Huronian. As to the sixth or final characteristic, that the group is defined by paleontology, it is to be said that the Huronian is so only so far as it is proved to be pre-Cambrian by the fact that it antedates by an immense interval of time rocks holding Cambrian fossils. It has so far yielded no recognizable fauna of its own.

Thus the only departure from the definition lies in the fact that the Huronian, while plainly in all other respects a group, is not to be correlated with any particular pre-Cambrian or other rocks by a comparison of fossils. The writer himself is not among those who accept paleontological correlations in the extreme way in which they have frequently been presented to us in the books; indeed, he is disposed to agree with those others who think that, while there has been a general similarity in development in different basins of rock growth, or even in different continents, the similarly named groups of these different basins and continents have hardly been always so exactly correspondent or even homotaxial as has generally been supposed. It would seem that the author of the quotation referred to held also somewhat the same views from the fact that he speaks of the ordinarily accepted groups as arbitrarily determined, in part at least. But, waiving such considerations, it would seem that one need hardly do more than ask the question—whether the great thickness of rocks in the Huronian series, not to speak of that included within the Keweenawan, is to be ignored in geological chronology merely because its exact geological equivalents in other regions are not strictly recognizable as such—to receive a negative answer.

The Huronian then is a true sedimentary group in origin, in volume, in chronological distinctness from other groups above and below it. It is not only *comparable*, as to volume, with the ordinarily recognized rock groups, it *exceeds* most of them;

besides which it is separated from adjacent rocks by tremendous unconformities, representative of immense lapses of time, while in many cases the later fossiliferous groups are divided from one another by no sharp structural or even paleontological line. Now similar arguments would establish the group rank also of the Keweenaw series. These two groups represent a great lapse of time hitherto ignored. They belong to that great gap—which they only partially fill—lying between the Cambrian and the Archæan, as do also other rock groups in other portions of the world.

As now generally accepted and presented in the books, the geological column makes no provision whatever for these great intermediate groups of strata; nor is there any uniformity of practice as to their classification among those geologists who have written upon them. Even among those who believe in its complete structural separateness from the upper Cambrian strata the Keweenaw series has been classified now as the upper portion of the Archæan, now as the lower portion of the Cambrian. The Huronian when first recognized by the Canadian Survey was put in the Cambrian; later the same survey threw it into the Archæan. In the same way the immense succession of rocks which lies below the great unconformity of the depths of the Grand Cañon of the Colorado has been classed now as Cambrian, again as Archæan. But all of these groups are plainly wholly separate in point of time of production from both the Cambrian above and the Archæan below, each of them being fully entitled to a classificatory value equal to that of Cambrian, Silurian, etc. It seems evident, then, that they should receive admission, as entirely separate groups, to the geological column. But their admission to this column appears to involve a difficulty, and also a further important modification of the column. As has already been fully admitted, we cannot speak, certainly in the present stage of the science, of Huronian rocks in portions of the world remote from the Lake Superior Province. In other words, we cannot correlate directly with the Huronian any pre-Cambrian fragmentals elsewhere found, since such fragmentals might, so far as we are able to determine, be rather the equivalents of the Keweenawan or of some series belonging in the gap above the Keweenawan, in that below it, or again in that below the Huronian. We must, therefore, in constructing our column, in some way indicate that these groups have individually a recognizable extent which is as yet only local. But plainly some term is necessary to cover all of these groups collectively; in other words, all of that great gap which lies between the base of the Cambrian and the summit of the Archæan gneissic and schistose basement. This name cannot be one of the group rank, since it

must cover two or more groups itself; it must be of the same rank with Paleozoic, Mesozoic, and Cenozoic.

To follow out the idea that is contained in these three terms, the new term should have some reference to the life-conditions of these early times. That life existed during the accumulation of the pre-Cambrian fragmentals seems to me to admit of no question. For proof of this I will not appeal to the high development of the first Cambrian fauna, nor to the fossil or fossil-like forms which have been found in the quartzites of southwestern Minnesota, in the Keweenaw series of Lake Superior, in the pre-Cambrian quartzites of Newfoundland, and in the Grand-Cañon series of Arizona; nor will I advance the usual arguments in favor of an Archæan life. I will only bring forward the wide-spread occurrence, within the Huronian of the Lake-Superior province, of two materials whose organic origin would seem to be beyond question. I refer to the carbonaceous shales and to the iron carbonates—or derivatives from iron carbonates—often associated with them. It is somewhat singular that these materials have been largely ignored in the various discussions that have taken place during many years past as to the existence or non-existence of life in pre-Cambrian times. It is true that the iron oxide accumulations of the Archæan have been used in this connection very often; but a doubt always remains as to whether these may not possibly be of chemical origin. In the case of the iron carbonates associated with carbonaceous shales in the Huronian, however, it does not seem that any such question can arise, since, as I have tried to show elsewhere, this association is one for which we can imagine no possible explanation other than that generally given to account for the association of similar materials at various higher geological horizons, notably the coal measures. Again, the carbonaceous shales themselves, taken alone, furnish an equally strong argument; for, while a doubt as to an organic origin for the graphite masses of the Archæan may perhaps be entertained, no such doubt can be admitted with regard to these shales, the carbonaceous matter of which is mingled with argillaceous fragmental material, whose accumulation in water by the ordinary processes of sedimentation must be taken as certain. Moreover, this carbonaceous matter, in the case of those shales which are separate from the iron carbonate accumulations, as well as in those that are associated with this carbonate, seems often to be distinctly *organic matter*, that is to say, is hydro-carbonaceous. We need not question, then, the existence of life during the accumulation of part if not all of the pre-Cambrian fragmentals. The *nature* of the life that then existed, however, we know practically nothing about, since, with the exception of those few doubtful forms already re-

ferred to, no fossils whatever have been met with in these ancient formations. The only things, then, that we can affirm with regard to the life of these early periods are, that it existed, and that we know nothing of its nature. I have already indicated my anticipation of the discovery of the remains of faunæ earlier than any of those with which we are now acquainted; though it may be that those are correct who imagine that no such remains will ever be brought to light, because of the probability that the earlier forms of life were unprovided with hard parts.

The general term to be used to cover the great pre-Cambrian interval should then express the existence of this early life, and our present ignorance with regard to its nature. During the year and a half that such an addition to geological nomenclature has been under discussion between myself and several of my fellow-geologists, many terms have been proposed and discussed. Some of these have been rejected because, though sufficiently appropriate, they have already been too generally used in other connections. Others again seemed inadmissible because, while expressing well the idea to be presented, they were made up of derivatives from the Greek not ordinarily met with in the English language, and were too cumbersome and pedantic in sound. Others again, like *Proterozoic* (*πρότερος*, *earlier*), suggested by Mr. Emmons, while simple and made from a Greek word of not too uncommon use, seemed to fail in covering the ground sufficiently. I have therefore been disposed to return to a term early proposed by Professor T. C. Chamberlin, to whom indeed is to be assigned the first suggestion of the use of a single name to cover all of the pre-Cambrian fragmentals. I would advocate therefore, the use of the term *Agnotozoic* (*ἄγνωτος*, *unknown; ζωή*, *life*), to cover all of the geological interval lying between the base of the Cambrian and the summit of the Archæan crystallines. This proposal I make with a good deal of hesitation, and only after consultation with several of my fellow geologists. Not that I have any question as to the need of such a term, nor as to the hitherto too much ignored truth which I conceive it to express; my hesitation arises simply from the feeling that so important an addition to geological nomenclature should hardly be attempted by any single individual.

I ought not to conclude without alluding to one objection to the proposed new term—or indeed to any term designed to have the same scope—brought forward by one of my colleagues; this is, that while the upper limit of the proposed Agnotozoic is clearly enough defined by the basal Cambrian fauna above, the lower limit is not similarly defined, and that if we accept the view of some geologists that metamorphism

has progressed upwardly to irregular distances among the early fragmentals, we should be calling fragmental rocks of one region Agnotozoic, while the crystalline schists, representative of these in other regions, would be classed as Archæan. In reply to this objection I should say, in the first place, that a number of the geologists who of later years have concerned themselves with the early formations have been tending more and more to the conclusion that there is always a reasonably easy line of demarkation between the true Archæan crystallines and the overlying fragmentals. My own experience has led me strongly toward such a view. But even if this be not the case, it is to be said that the lower limit of the proposed Agnotozoic would on the whole be but little more arbitrary in any universal application than are those lines generally accepted as established paleontologically. These paleontological boundaries have generally been established in the first place for a restricted region, and their application to other geological basins, and particularly to distant continents, has always been in a measure an arbitrary one. It should be understood distinctly that the term is proposed to cover, not any non-fossiliferous formations lying beneath the Cambrian—since so far as they are in complete conformity with the overlying Cambrian they *may* be merely its downward extensions—but such non-fossiliferous and distinctly fragmental and sedimentary rocks as are separated from the Cambrian base by a genuine wide-spread unconformity; that is, by a structural break indicative of an enormous lapse of unrecorded time.

ART. XL.—*Rounded Bowlders at high altitudes along some Appalachian Rivers;* by I. C. WHITE.

IN a paper read at the Minneapolis meeting of the American Association the writer described some deposits along the Monongahela and Teazes valleys in West Virginia, that seemed to furnish strong confirmation of Professor Wright's hypothetical ice dam. Since the preparation of that paper many other facts bearing on the question at issue have come under my observation, and they are here placed on record with a view of assisting those who are making a specialty of surface geology to the correct solution of the problems they involve.

That the terrace deposits along the Monongahela, Allegheny and Ohio valleys were formed during a *submergence* of some kind, will, I think, hardly be questioned by any geologist thoroughly familiar with the nature and extent of the deposits themselves; for there are numerous localities where the evi-

dence would seem to be conclusive that these valleys had been eroded to near their present depths before the deposition of the rounded bowlders, clay, logs, leaves, and other trash that constitute the deposits. The single fact that they disappear abruptly would seem to be sufficient evidence that they did not originate, as some have supposed, from the detrital matter which the streams left along their banks in the original erosion of these valleys. No one, it seems to me, could question the submergence of the upper Ohio valley in recent geological times, who has carefully examined the deposits in the old, and abandoned Teazes valley, along the C. & O. R. R., through Mason and Cabbell counties, West Virginia. Hence I think the submergence may be considered as established ; the only question open being whether this submergence was general, involving a continental movement, submerging the valleys east from the Allegheny Mountains, as well as those west from the same, or whether the submergence of the Ohio and its tributaries was of a local character and accomplished through the agency of the glacial dam which Professor Wright believes existed in the region of Cincinnati. Some of the facts now to be enumerated may be equally well explained on either hypothesis.

About ten miles above the mouth of the Big Sandy River, and on the West Virginia side, a considerable deposit of small water-worn bowlders occurs near the summit of a broad, flat-topped hill, at an elevation of 400 feet above the stream, or not far from 900 above tide. This deposit is interesting from the fact that it is the only one that I was able to find between the point in question and the source of the river, nearly 200 miles above, though the failure may be satisfactorily accounted for by the precipitous character of the bounding valley walls, and the unusually soft and easily disintegrated nature of all the surface rocks; for all along the Big Sandy, even the Pottsville conglomerate becomes rotten, and very readily crumbles into loose sand, which, carried down by the rain, fills up the channel of the river and has thus given name to the stream. It is not assuming too much to state that these rounded bowlders of local coal-measure sandstone could hardly have resisted the elements during the long time since the Big Sandy valley existed at this 400-foot level.

The Guyandotte river puts into the Ohio next above the Big Sandy, and on this stream about 100 miles above its mouth, a large deposit of rounded bowlders was observed on the inner side of one of its curves opposite the mouth of Panther Creek. The bowlders cease at 150 feet above the stream, or about 925 feet above tide, according to levels run by Captain Miller, of the Trans-flat Top Land Company.

The bowlder deposits are found in greatest quantity about

the junction of streams, and consequently at the mouth of Elk River, on the great Kanawha, in the vicinity of Charleston. Vast numbers of them extend to near 250 feet above this river (800 feet above tide), and scattering ones are found up to 390 feet or 945 feet above tide. Here, along with the hard rocks of local origin, we find great numbers that have come from the Blue Ridge in Virginia and North Carolina, nearly 200 miles distant.

The effect of local causes in both forming and preserving these deposits is well illustrated along the great Kanawha, for with a single exception (near the mouth of Paint Creek), no other deposit of bowlders exists between Charleston and the mouth of Gauley river, a distance of 40 miles. At this latter point, however, the quantity of rubbish thrown down seems to have been so great that a considerable thickness of rounded bowlders still exists on a comparatively steep slope up to 150 feet above the river; but here the ascent becomes almost precipitous and the deposit disappears.

On Elk River, two miles above Charleston, an example may be observed very similar to the famous one of Teazes valley, though on a much smaller scale. Here a stream, known as Two-mile, enters Elk, and on following up the same for a distance of two miles, we find one of its branches heading in a narrow valley up against a creek which flows in the opposite direction and enters Elk about five miles above Charleston. The divide between the two streams is almost imperceptible, and it is covered with a deposit of clay and rounded bowlders at an elevation of 175 feet above the level of the Elk, thus proving that an arm of the same passed through this valley during the epoch of submergence. From Major Campbell, of Charleston, to whom I am indebted for the elevation of this old water-way, I learn that another abandoned valley precisely similar to the one at the head of Two-mile, may be seen about ten miles farther up Elk River.

It is a remarkable fact that along the Ohio valley, between Point Pleasant and Rochester, with a single exception, transported bowlders have never been reported above the level of the third terrace, or say an extreme elevation of 100–125 feet above low-water. I have myself examined the hill-slopes at probably 200 different points between the mouth of the big Kanawha and the Beaver 250 miles above, and with the single exception noted, not one water-worn bowlder has been observed above the uppermost of the broad river bottoms. We cannot doubt that they once existed far up these river hills, since, at Pittsburgh, above, and Charleston, below, they occur several hundred feet higher than along the intermediate Ohio. It is very probable that their absence is due to the very steep hill slopes that exist throughout the region in question, thus permit-

ting the few stranded bowlders to be shed into the valleys by subsequent erosion.

All who are familiar with the region about Pittsburgh, and as far down the Ohio as Bellevue, cannot have failed to observe the immense deposits of transported bowlder trash that have accumulated about the junction of the Allegheny and Monongahela rivers. The beautiful valley of East Liberty and Homewood owes its origin to the submergence of this region to such a depth that a branch of the Monongahela once extended across the divide near Homewood, and connected with the Allegheny several miles above the present junction. The extreme elevation of the great bowlder heaps around Pittsburgh is about 300 feet above water level (1,000 feet above tide). At Sewickley the great deposit ends about 160 feet above the river; near the mouth of Beaver it is only 125 above; and still farther down the Ohio the top limit of the deposit declines to 100, and often to not more than 80 feet above low water.

In the vicinity of Sewickley, during the past year, I discovered transported bowlders extending up to nearly 600 feet above the Ohio, or more accurately 1,250 feet above tide. It is true the same observation had previously been made along the Ohio near Sisterville, but this being then the only known instance of water-worn bowlders at such a great elevation, and only a few of them being found, it was considered probable that the Indians had carried them up from the valley for some purpose. They are not abundant at this great elevation in the vicinity of Bellevue and Sewickley, but the farmers report that they plough them up occasionally in every field for about one mile back from the river. None was seen of a diameter greater than 6 inches. From the fact that these few scattering bowlders are confined to the river valley, I still think it very probable that they were carried to these high levels by the Indians. Granitic bowlders of small size have also recently been found near Washington, Pa., at the head of Chartiers Creek, which empties into the Ohio river a short distance below the mouth of the Allegheny. I have seen only a few of these, but Mr. A. J. Montgomery, on whose farm they occur, reports that a large number of them were found in digging a ditch for the natural gas main, a short distance outside of the borough. The elevation of the Chartiers Valley railroad depot is 1,030 feet above tide, and the granitic bowlders picked up near Mr. Montgomery's were about 20 feet higher. This locality is so far (30 miles) from the Ohio Valley that we cannot, with much degree of plausibility, ascribe the presence of the bowlders to Indian transportation, and especially the regular bed of them which Mr. Montgomery saw in the Pipe Line ditch. As the Chartiers Valley is almost a direct (southward) continuation of the Alle-

gheny, it seems probable that these granite bowlders were transported to the head of the Chartiers by the current which set down the Allegheny during the epoch of submergence, having been gathered up by the latter stream where it crossed the terminal moraine below Franklin.

Near the mouths of the Conemaugh, Youghiogheny, and Cheat Rivers, large deposits of rounded bowlders extend up 250–300 above the present water level, but as we ascend any of these streams the bowlder line gradually declines until along the upper reaches of each stream, the deposits fail at 75–100 feet above water level.

Owing to the nature of the topography, and the country rock along the draining streams, the region along the Upper Monongahela has these terrace deposits in better preservation than any other with which the writer is acquainted, and this is especially true of the West Fork branch of that stream. It is along this line that the existence of a great submergence which covered the country with a thick coating of transported material up to a certain level, is most conclusively shown. In the region of Morgantown, on the main Monongahela, these terrace deposits end at about 275 feet above low water, or 1065 feet above tide, while at Fairmount, 26 miles above, there is a vast amount of this terrace material thrown down about the junction of the Valley and West Fork Rivers, and the upper limit of the same is a little over 200 feet above low water, which is here 850 feet above tide.

About 20 miles farther up the river (West Fork), near Shinnston, the upper limit of the terrace material is found at 160 feet above the water, but here the latter has an elevation of about 885 feet above tide.

At Clarksburg, where the river unites with Elk Creek, there is a wide stretch of terrace deposits, and the upper limit is there about 1050 feet above tide, or only 130 feet above low water (920) while at Weston, 40 miles above (by the river), these deposits cease at 70 feet above low water which is there 985 feet above tide. It will thus be observed that the upper limit of the deposits retains a practical horizontality from Morgantown to Weston, a distance of 100 miles, since the upper limit has the same elevation above tide (1045–1065), at every locality.

These deposits consist of rounded bowlders of sandstone, with a large amount of clay, quicksand and other detrital matter. The country rock in this region consists of the soft shales and limestones of the Upper Coal-measures, and hence there are many "low gaps" from the head of one little stream to that of another, especially along the immediate region of the river, and in every case the summits of these divides, where they do not

exceed an elevation of 1050 feet above tide are covered with transported, or terrace material, but where the summits go more than a few feet above that level we find no transported material upon them, but simply the decomposed country rock.

A fine example of one of these bowlder-covered divides may be seen at the mouth of the Youghiogheny River, back of McKeesport, Pa. The "divide" in question is one between the waters of Long Run, which puts into the Youghiogheny, two miles above McKeesport, and that of another little stream which heads up against it, and flows into the Monongahela within the city limits. The divide between these two waterways, although 275 feet above the level of the river, is almost imperceptible in a broad, and bowlder-covered valley through which there is not the slightest doubt that the waters of the Youghiogheny once flowed during the epoch of submergence.

When we cross to the eastern side of the Alleghenies, bowlder beds are also found at high elevations along all the streams which have their sources in the mountains. At Piedmont, on the North Potomac, where water-level is about 910 feet above tide the rounded bowlders cease at 150 feet above the stream, while at Cumberland, 50 miles below, where the river level is 615 feet above tide the rounded bowlders can be traced up to 300 feet above the stream.

That this region along the Potomac has been submerged during recent times, seems fully proven by some facts observed along Patterson's Creek, 8 miles below Cumberland; for here the submergence is attested by the presence of a bed of curious conglomerate, made up of angular and water-worn fragments of local rock (limestone, slate, sandstone, &c.) the cementing material being lime and iron. The stratum is 1–3 feet thick, and the remnants of it encircle the valley of the stream where it is found 10–15 feet above water level. It is reddish colored from iron stains and would seem to correspond quite well with the "Bryn Mawr" conglomerate described by Prof. H. Carvill Lewis, from the vicinity of Philadelphia. It seems to have once covered a considerable area in the Patterson's Creek valley, since Col. Jno. A. Robinson, who first called my attention to the bed, informs me that he has observed fragments of it five miles up the Patterson's Creek valley. The elevation of the B. & O. R. R. station at the mouth of Patterson's Creek is 568 feet above tide, and the level of the conglomerate is 20 feet higher, or 588 feet above tide.

A narrow, synclinal valley of Marcellus slate, bounded on either side by arches (ridges) of Oriskany sandstone, which carry on their slopes the outcrops of the Marcellus or Selinsgrove limestones, furnishes a sufficient reason for the origin of this conglomerate in a submerged valley.

Along the South Potomac, the Shenandoah, the James, and other rivers of Virginia, large deposits of rounded bowlders are found far above where the present streams ever rise, and the similarity of the deposits to those occurring along the rivers west of the Alleghenies is very striking. It is barely possible they have had a common cause in a submergence of continental extent, but at the same time there can be no doubt that the hypothetical "Ice Dam" of Prof. Wright, would satisfactorily account for all the phenomena of surface geology which exist along the rivers west from the Alleghenies.

Submergence, with re-elevation in comparatively recent times, will then give a sufficient explanation for the existence of the elevated bowlder deposits in the vicinity of Washington, D. C., Richmond, Philadelphia, and possibly as far west as Cumberland, but along some of the Appalachian rivers we meet with a class of facts that neither the "Ice Dam" hypothesis of Prof. Wright, nor the (seemingly demonstrated) Atlantic coast submergence will satisfactorily explain. Reference is here made to the bowlder deposits that occur far above the level of the present streams, when we have followed them so near their sources as to be high above the limits of Prof. Wright's "Ice Dam," and also still higher above any evidence of continental submergence. One of these remarkable deposits may be seen on Cheat River, in Tucker County, West Va., a short distance above St. George. The elevation of the river's bed is there about 1500 feet above tide, and yet great deposits of rounded bowlders and other detrital material are found lining the valley in terraces up to 175 feet above the level of the stream. It has occurred to me that possibly during the long cold of the Glacial epoch, the snows may have accumulated to a depth sufficiently great along the Alleghenies to form local slides of considerable extent, which might dam up the streams in their upper reaches where they flow along the slopes of the mountains in narrow gorges, like the Cheat in the vicinity of Rowlesburg, a few miles below where the terrace deposits in question have been noted.

Mr. N. D. Adams, of St. George, and the present editor of the Wheeling Register, informs me that near the county seat of Tucker there is a very high hill bordering the valley of Cheat River, and that circling back around it is an old river channel filled with water-worn stones and other transported trash at a considerable elevation above the level of the river. This, together with the terrace deposits observed by myself above St. George, would seem to prove that the valley of this stream has been submerged in that region within recent geological time, or at least not earlier than the Glacial epoch, and yet I can see no explanation for the submergence in this or other similar

cases except the one suggested above. It is true that the rivers which flowed from the Appalachian plateau after the accumulated snows of the Glacial epoch began to melt away, would vastly exceed in volume any floods with which we are now acquainted, but still they would culminate far below the 175-foot level, and we can scarcely believe that subsequent erosion has deepened the valleys so much as to make up for the difference.

West Va. University, Morgantown, Aug. 1st, 1887.

ART. XLI.—*Description of an Iron Meteorite from St. Croix Co., Wisconsin;* by DAVENPORT FISHER. (With Plate V.)

THE mass of meteoric iron described in this paper was plowed up three years ago (1884) in a cornfield on the farm of Mrs. Jenette Rattary in Hammond Township, St. Croix County, Wisconsin. (The exact description of the forty acres is:—North ½ of S. W. ¼ of Sec. 31, Township 29, Range 17 West.)

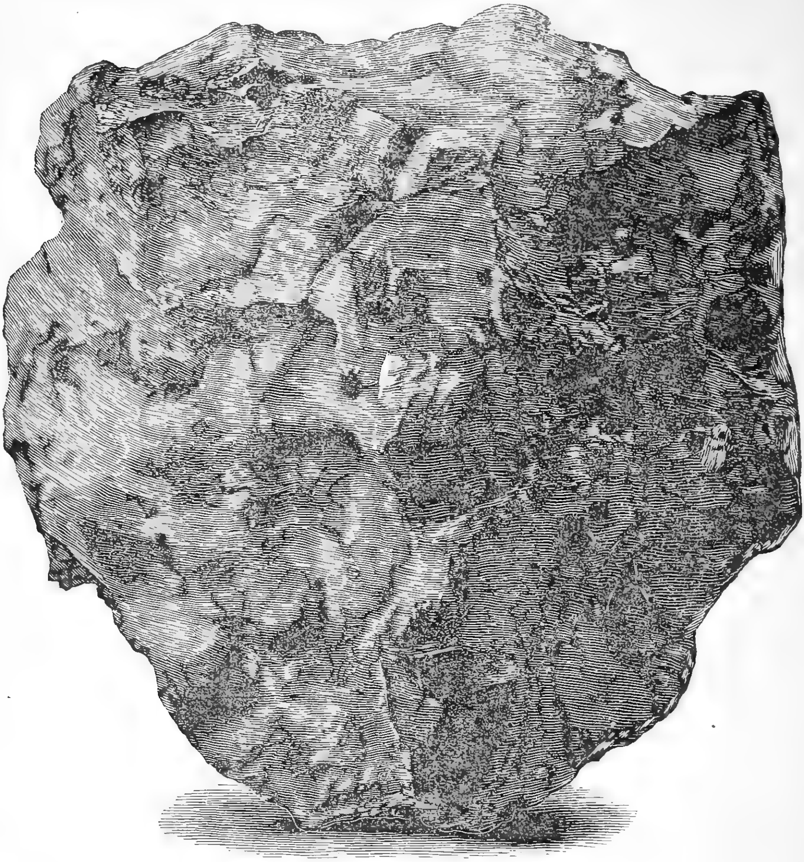
It attracted attention from its weight and silvery luster where freshly abraded, and was supposed to contain silver, but its real nature was not suspected, and it lay about the farmyard until last winter. At that time, during the excitement about iron ores in that neighborhood, a speculator chanced to see it and he at once paid fifty dollars for an option on the forty acres to prospect for iron ore. The mass was sent to me for analysis, and on its being reported to be a meteorite was reclaimed by the owner, and it was not until I visited the region in May last, that the facts of its discovery were ascertained.

It was struck by the plow near the surface of the ground, in a field that had been cultivated for corn for several successive years, and the farmer was quite certain that it could not have been there the year before, and its fresh appearance noted later, testifies to the probability of its having recently fallen. It is quite remarkable that it kept so bright during the three years it lay in the farmer's yard. No similar pieces have been seen, nor does this show signs of fracture.

The mass has been considerably disfigured by attempts to chisel off pieces at different points, and one piece was detached and forged into a spike, but this I did not see. When it reached me it weighed 53 pounds (24 K.). It is of irregular shape, as shown in the accompanying cut, engraved from a photograph I had taken when it first reached me.

Its dimensions are 8 by 8 inches across the face and 7 inches through, in the thicker part, but with an average thickness of

4 to 5 inches. The back side, as the view is taken, is nearly flat and pretty uniformly covered with circular pittings. On



this side, it presents the ordinary appearance of most masses of meteoric iron, the surface crust having entirely disappeared. It seems probable that it lay with this surface in contact with the ground during the three years after it was dug up, and the crust disappeared by the ordinary process of weathering. The front side is less regular in shape and shows several large depressions. This surface is largely covered with the fused crust which is heaped up in ridges and shows all the perfections of the lines of flow characteristic of irons which have been picked up immediately after their fall; the only change being a partial oxidation of this film so that it appears in places brown instead of black. This character of the St. Croix meteorite,

independent of the confirmatory evidence afforded by the circumstances of its history, would make it probable that its fall did not precede by many months the date of its discovery.

A careful analysis of the iron was made by the writer and his assistant, Mr. Chas. G. Allmendinger, with the following results:

Sp. gr. $\overset{\text{1st}}{7\cdot601}$—$\overset{\text{2d}}{7\cdot703}$ (Two different pieces).

Iron	89·78
Nickel	7·655
Cobalt	1·325
Phosphorus	·512
Silica	·562
Carbon	traces
Copper	traces
Tin	traces
	99·834

It contained nodules of troilite, 3 appearing in one section, from 3^{mm} to 12^{mm} in diameter. No other inclosures were detected by me.

I am indebted to Mr. Geo. F. Kunz for sections cut from the mass and polished for etching, and I leave to him the description of the Widmanstätten figures, etc. The meteorite now forms a part of the collection of Yale University at New Haven.

Note by Mr. George F. Kunz.

When dilute nitric acid is applied to the St. Croix County iron, the Widmanstätten figures quickly appear, but unlike the Glorieta and Staunton meteorites, it could not be etched to any depth, because on long continued application of the acid, the entire surface of the iron rapidly dissolves away, leaving only projecting points of taenite. Hence it was found impossible, as had been at first intended, to reproduce the figures directly from an electrotype taken from the iron. The figures are cubical rather than octahedral in arrangement and more closely approach the Jewellite group of Meunier, particularly the Dickson County iron; in form the entire arrangement resembles the Schwetzite Werchne-Udinsk Siberia group, but the figures are about one-third their diameter. It also resembles somewhat the Trenton, Wisconsin iron, but still differs from all of these. Troilite is present in nodules 5 to 10^{mm} in diameter and also filling the irregular fissures some 50^{mm} long and 1 to 3^{mm} wide. The figures, shown on Plate V, are an exact reproduction natural size by the admirable Kurtz process.

ART. XLII.—*Combinations of Silver Chloride with other Metallic Chlorides;* by M. CAREY LEA.

IN a series of papers lately published, I have expressed the view that the principal and characteristic product of the action of light on the silver haloids is a combination of the haloid with a small proportion of its own subsalt. Such was the result of my analyses, and the opinion was supported by the tendency which the silver haloids were found to have to unite with foreign matters, such as many dyes and other organic compounds, showing the existence in these silver haloids of a singular disposition to form compounds outside the laws of atomic proportion.

This opinion finds additional support from another argument and a more nearly parallel case, for it appears that silver chloride (and doubtless the other silver haloids) can unite with small quantities of certain other metallic chlorides. That an actual combination, though one quite outside of atomic proportion, takes place, is proved by two facts; first, that the chloride with which the silver haloid unites, though soluble in water, is not removable by water; again, that the properties of the haloid are markedly changed.

This combination with another metallic chloride furnishes a much nearer parallel case to the photosalts than does the combination with a dye. For if silver chloride is found to be capable of taking up a small quantity of ferric or other chloride, and of retaining it so firmly that it cannot be removed by washing, and only with some difficulty by HCl, we are thereby justified in admitting that the silver haloid may easily form a stable combination with a small proportion of its own subsalt.

In all these compounds the tendency seems always to the combination of a large proportion of the silver haloid with a small one of the other substance, whether the latter is a dye, another chloride, or a silver subsalt—all show the same disposition, so that I am justified in saying that my view of the nature of the photosalt is supported by the existence of many analogous bodies.

These compounds of silver chloride and other metallic chlorides form when the silver haloid is in presence of their solutions at the moment of its precipitation.

AgCl with Fe_2Cl_6.—When to dilute HCl is added, first, ferric chloride, then solution of silver nitrate, the silver chloride thrown down is not white but buff-colored. The ferric chloride which has united with the silver chloride cannot be removed by washing. Agitating with HCl dissolves out part, but not all. It is very interesting that this small quantity of iron pro-

foundly affects the sensitiveness of the silver salt to light. To make an accurate comparison, two solutions of silver chloride were precipitated, the one from pure HCl, the other from HCl mixed with Fe_2Cl_3; both were shaken up with HCl, so as to remove all the more loosely combined iron salt from the one, and to place the two under exactly corresponding conditions, the presence of the iron salt alone excepted. They were then washed. When both were exposed together to light, the difference was extraordinary. The normal AgCl had passed to a full violet, with an exposure which produced on the other scarcely any visible effect. Even after an exposure to diffuse light of two hours, the difference was still very striking.

AgCl with CoCl.—When cobalt chloride is added to HCl, and then solution of silver nitrate, a pinkish precipitate is obtained, whose sensitiveness to light is less than that of normal silver chloride. But the diminution of sensitiveness is far from being so great as in the case of AgCl precipitated in presence of ferric chloride.

AgCl with other chlorides.—Both nickel chloride and manganous chloride attach themselves to silver chloride when the latter is precipitated in their presence. Cupric chloride seems to have no such tendency. Gold chloride shows a marked tendency to attach itself to AgCl. When silver nitrate is added to dilute HCl with which a little auric chloride has been mixed, the precipitated AgCl has a reddish shade. Continued washing renders this paler but does not seem to remove it. After ten decantations, each with a hundred volumes of water, the color imparted by the gold is still visible. What influence the auric chloride has on the sensitiveness of the silver salt it is not easy to say, as the gold present is quickly reduced by exposure to light, so that the AgCl, instead of passing to violet and chocolate as in the case of pure AgCl, gradually darkens to a pure black.

The facility with which these compounds are formed explains the necessity in analytical determinations of silver as chloride, for digestion for a considerable time with dilute HCl. Even then it is very doubtful if all the foreign chloride is removed. Ferric chloride is especially adherent. Indeed it has been said that when iron once comes into contact with silver it is next to impossible to get rid of it, and the reason lies in the strong affinity which the two chlorides have for each other. Accordingly much silver nitrate sold as absolutely pure contains iron, evidently carried down with the silver chloride when precipitated in the manufacture.

These reactions of AgCl are interesting in several ways.

They support the theory I have proposed, of the photosalts

being compounds of two chlorides of silver not combined in definite proportions, by establishing the existence of other analogous compound chlorides.

Again, the sensitiveness to light of AgCl is so strongly modified by mere traces of ferric chloride, that evidently a quantity of the latter substance, quite too small to visibly affect the color of the AgCl, may materially change its sensitiveness, thus affording an illustration of what takes place in the latent image, where the presence of a quantity of Ag_2Cl, too minute to be visible, is sufficient to powerfully influence the substance combined with it.

It also furnishes an explanation for a well-known fact that has hitherto seemed anomalous. It has long been known that a trace of mercuric chloride suffices to greatly diminish the sensitiveness of silver chloride to light. This isolated fact now becomes simply one of a series; AgCl combines with a small proportion of mercuric chloride just as it does with other metallic chlorides, those of the iron triad for example, and does not give it up when washed.

Debray (quoted in Gmelin-Kraut, article Silver), has indeed expressed the opinion that the mercuric chloride can be entirely removed by washing with water. To fix this point I have sought for a convenient means of detecting small quantities of mercuric chloride in presence of AgCl, and have found it in a solution of stannous chloride made strongly acid with HCl. Pure AgCl is not darkened by this reagent, provided that light is carefully excluded, but if mercuric salt is present, a brown or brownish black coloration results. Long washing has with me wholly failed to remove the mercuric salt. I therefore look upon the combination as one of considerable stability.

All these combinations diminish the sensitiveness of AgCl, but this effect is greatly stronger with those chlorides which easily part with one equivalent of chlorine, as we saw in the case of ferric chloride. Mercuric chloride acts in the same energetic way.

It seems indeed that the reduction of sensitiveness in these cases is somewhat out of proportion to the amount of chlorine that could be yielded up by the trace of the foreign chloride which is combined with the AgCl. But this is, perhaps, to be explained by this trace of chlorine holding in check the initial movement toward reduction.

It is worth observing that experiment and observation are constantly tending to enlarge the number of substances with traces of which the silver haloids show themselves capable of uniting, with great modification of their properties as a consequence.

The reduction of sensitiveness that results from the presence of

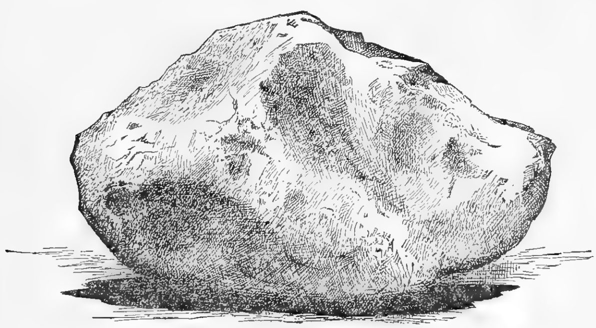
certain other chlorides, will undoubtedly in the future be of great value in aiding toward a solution of the problem of rendering permanent photographic images in natural colors. Indeed, it was Poitevin, I think, who found that his colored images resisted light better when treated with lead chloride and dextrine. The property was observed, but the nature of the action remained obscure. We now see its explanation in the tendency of the lead salt to check reduction. Zinc chloride I found available like lead chloride, to regenerate white silver chloride by the action of light on colored photochloride, and thus to give aid toward that very difficult requirement in heliochromy, that white light shall express itself by producing white.

Philadelphia, September 24, 1887.

ART. XLIII.—*The Rockwood Meteorite;* by J. EDWARD WHITFIELD.

THE Rockwood meteorite was found about the middle of March, 1887, by Mr. Elihu Humbree on the range of the Crab Orchard Mountains. The field in which it was picked up is now owned by Mr. W. B. Lenoir, and is situated $8\frac{1}{2}$ miles west from Rockwood, Tenn., in Cumberland County. The material for analysis was received from Messrs. Ward and Howell, of Rochester, N. Y., the present owners of the meteorite, to whom we are indebted for the privilege of description.

1.



$\frac{1}{6}$ Natural size. (The main mass.)

There were three pieces found, the smallest measuring $4\times3\times2\frac{1}{2}$ inches and weighing 3 pounds $10\frac{1}{2}$ oz.; the next larger measuring $7\frac{7}{8}\times6\frac{1}{2}\times2\frac{3}{8}$ inches and weighing 5 pounds $13\frac{1}{2}$ oz.; and the largest, an irregular egg-shaped mass a little flattened on one side, measuring $14\frac{3}{4}\times10\times8\frac{1}{2}$ inches, with a weight

of about 85 pounds, and sp. gr. of 4·240. An idea of the appearance of this piece can be had from the foregoing cut, which is from a photograph reduced to $\frac{1}{6}$ natural size.

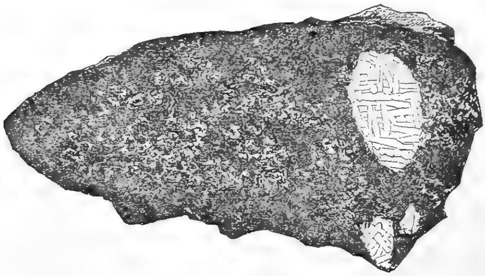
The mass is quite brittle, very hard to saw, but easily broken by hammering. Cut slices show many irregularly shaped stony fragments with some nodules, the largest seen being about $\frac{5}{8}\times\frac{3}{8}$ inches on the surface diameter. In the larger slices the stony part is so broken as to give the polished surface a brecciated appearance. In analysis the metallic portion was freed from the mineral part by crushing to rather fine particles and separating by the aid of a magnet. This was again treated in the same manner, and the resulting metal washed with alcohol and quickly dried; by this method it was found possible to free the metal from all but the merest trace of stony substance.

The metallic portion proved to be an alloy, rich in nickel, as is shown by the following figures:

Fe	87·59
Ni	12·09
Co	trace
Cu	"
P	none
S	"
	99·68

The metallic grains seem to be quite evenly distributed through the mass. In but one instance does a nodule appear to have attained a size larger than that of a pea, and on the section of this nodule we were able to obtain the Widmannstätten figures by etching. Cut No. 2 shows the polished slice containing this nodule, natural size.

2.



Natural size.

The rocky part, after being freed as well as possible from metal, was finally ground and digested with dilute hydrochloric acid, and the resulting soluble and insoluble portions investi-

gated separately, but from the fact of there being a number of minerals mixed together, no satisfactory conclusions could be drawn from the examination. The mass was therefore analyzed as a whole with the following result:

SiO_2	41·92
Al_2O_3	9·27
FeO	22·94
CaO	9·09
MgO	8·76
Fe	3·75
Ni	1·74
Cl	0·18=0·32 $FeCl_2$
P	0·65
S	1·58
	99·88

By the analysis of the portions soluble and insoluble in dilute acid, it was found that the greater part of the lime and but a trace of the magnesia had gone into solution, proving the absence of olivine, and giving good grounds for the supposition that the rocky portion is mainly a mixture of anorthite and a silicate related to augite, but very rich in iron.

It will be noticed that the ratio between iron and nickel in the metallic portion is greater than that in the rock. This is accounted for by the fact that in the rocky part of the meteorite, the iron, as metal, has been greatly oxidized, as is shown by the large amount of rust covering the specimen, caused no doubt by the chloride of iron present, and is reckoned as FeO, accounting for the large proportion of iron in the supposed augite.

Owing to the bad condition of the fragments subjected to analysis we have no grounds on which to compute the phosphorus and sulphur as schreibersite and troilite, but from the fact of these minerals being among the more common constituents of this class of meteorites, and also that in the main analysis of the rock portion phosphorus and sulphur were found, it is probable that the phosphide and sulphide of iron are two of the minerals present.

One of the polished slices contained a nodule of about ½ inch diameter, which was sacrificed in order that its nature might be determined, and the following figures give the results of analysis. The mineral was finely ground, the metallic portion, if any, separated by aid of the magnet and digested in dilute hydrochloric acid.

The insoluble portion was found to be 94 per cent, the composition of which is

SiO_2	51·85
Al_2O_3	4·52
FeO	13·26
CaO	1·09
MgO	29·28
	100·00

Giving the ratio of R″O to SiO_2=·93 : ·86, which corresponds well with the mineral enstatite, although in this case much of magnesia is replaced by iron. The soluble portion consisted of iron with a slight trace of nickel, which tends to show that the nodule contained some metallic particles which it was impossible to extract with the magnet. During the digestion in acid, as no sulphuretted hydrogen could be detected, we infer the non-existence of sulphides in the nodule.

The total mineral was also analyzed with the following results:

SiO_2	49·96
Al_2O_3	4·75
FeO	15·97
CoO+NiO	trace
CaO	1·15
MgO	28·15
	99·98

This meteorite then is a lithosiderite poor in metal, the metallic portion not exceeding 16 per cent of the mass. The stony part is probably anorthite and enstatite.

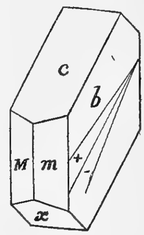
Chem. Lab. U. S. G. S., Washington, D. C., Aug. 26, 1887.

ART. XLIV.—*Triclinic Feldspars with twinning striations on the brachypinacoid;* by S. L. PENFIELD and F. L. SPERRY.

ON looking over the cleavage specimens of plagioclase feldspar in the collection of Professor Geo. J. Brush, especially those which would be classed as albite or oligoclase, we were surprised to find how many of them showed striations due to twinning on *i-ĭ* (010), in addition to the ordinary striations on the basal plane. These striations on the brachypinacoid have not been very prominently noted in text-books on mineralogy, and we have thought that it would be of interest to study them in connection with the chemical analyses of the feldspars. We are largely indebted to Professor G. vom Rath for our knowledge of the twinning striations on *i-ĭ* of the plagioclase feldspars. He showed* that they resulted from twinning accord-

* Jahrb. f. Min., 1878, 689.

ing to the so-called pericline law, that is the twinning plane is a plane at right angles to the macro-axis, $\bar{b}$. The two individuals in twin position are not united by the basal plane, when they would not quite match along the composition face, but by a plane deviating a little from the base, passing through the $\bar{b}$ axis, and so inclined that the four plane angles which its intersection makes with the prisms *M* and *m* and pinacoid *b* are all equal, this is the so-called rhombic section (*der rhombische Schnitt* of vom Rath). Owing to the variation in the axial angles of the triclinic feldspars, especially the angle between the $\breve{a}$ and $\bar{b}$ axes, which in albite = 87° 51½′, in anorthite 91° 12′, the direction of the rhombic section changes very greatly. This will be better understood from the accompanying figure and the following table copied from Tschermak.* If the direction above the line, parallel to the edge *c* : *b*, be called positive + and below negative −, the direction of the rhombic section in the different feldspars in the albite-anorthite series should be about as follows:



			% Na_2O	% CaO
Albite $Na_2Al_2Si_6O_{16}$ ------	Ab,	+22	11·8	0
Oligoclase --------------	Ab_3An_1	+4	8·7	5·2
Andesine ---------------	Ab_1An_1,	−2	5·7	10·4
Labradorite -------------	Ab_1An_3,	−9	2·8	15·3
Anorthite $Ca_2Al_4Si_4O_{16}$ ----	An	−18	·0	20·1

If these striations can be found, therefore, on *i-ĭ*, they should give a ready means of determining the position of the feldspar in the albite-anorthite series. The following analyses will serve to show the relation between the direction of the striations and the chemical composition of the feldspars.

Oligoclase and Albite.—In Professor Brush's collection, leaving out of consideration the crystallized specimens of albite and pericline, there are cleavage specimens from six different localities which show distinct striations upon *i-ĭ*. There are also a few others in which the striations are not very distinct, in all, nearly one-half of the specimens show these striations. On the basal plane the striæ are usually a little finer than on *i-ĭ*, and a rectangular marking is sometimes seen due to the meeting of the two sets of striations according to the albite and pericline laws. There is also a tendency for the feldspars to separate, or cleave, parallel to the rhombic section and a combination parting of this with the basal cleavage causes the feldspar to break out into wedge-shaped blocks. The following six analyses by Mr. Sperry are arranged according to the

* Lehrbuch der Mineralogie, 1884, 458.

percentage of CaO. All satisfy Tschermak's formula very well as mixtures of $Na_2Al_2Si_6O_{16}$ and $Ca_2Al_4Si_4O_{16}$. In VI there is an unusually large percentage of K_2O due to an admixture of microcline, which could be distinctly seen with the microscope on a section parallel to the basal cleavage. Below the analyses the proportion of anorthite to albite is given, K_2O being left out of the calculation, together with the per cent of anorthite, the direction of the rhombic section and the extinction angle upon *i-ĭ* measured with the polarizing microscope.

	I. Branchv'le, Conn.	II. Hitteroe, Norway.	III. Haddam, Conn.	IV. Miner'l Hill, Delaware Co., Pa.	V. Danbury, Conn.	VI. Pierrepont, St. Law. Co., N. Y.
No. in Brush collection,	*1790*	*1758*	*1757*	*1782*	*1764*	*1791*
SiO_2	66·58	66·83	66·06	66·34	65·73	63·76
Al_2O_3	21·26	20·88	21·57	20·72	21·32	22·67
Fe_2O_3	·07	·25	·18	----	·12	·41
CaO	1·18	1·46	1·80	1·85	1·95	3·05
Na_2O	10·26	10·36	9·57	9·44	9·66	6·89
K_2O	·76	·70	1·01	·98	·95	3·60
Ign.	·16	·27	----	·38	·19	·40
	100·27	100·75	100·19	99·71	99·92	100·78
Specific gravity	2·610	2·632	2·633	2·627	2·628	2·622
Ratio An : Ab	1 : 16·0	1 : 13·0	1 : 9·6	1 : 9·2	1 : 9·0	1 : 4·1
Per cent of anorthite,	5·87	7·25	8·94	9·20	9·70	15·17
Rhombic section	+12°	14°	13°	12°	10°	10°
Extinction on *i-ĭ* (010),	15°	15°	16°	12°	15°	6°

All of the above feldspars, with the exception of No. 6, are very similar and could be classified as albites, as they contain more than nine parts of the albite molecule to one of anorthite. Their extinction angle, 12°–16°, is near to that of pure albite +19°. In No. 6 we notice no very perceptible change in the direction of the rhombic section, as we should expect for so large an addition of the anorthite molecule; there is quite a perceptible change, however, in the direction of the extinction angle. Judging from the above, however, it will be safe to predict that where the striations on *i-ĭ* make an angle of about +12°, the feldspar will be a mixture of albite with from five to ten per cent of anorthite.

Feldspars more basic than oligoclase.—On the material at our disposal we have not been able to find many examples with striations on *i-ĭ*. One fine specimen, labeled labradorite from Labrador (No. 1732 in Professor Brush's collection), polished on the brachypinacoid to show the beautiful colors so common in that species, shows three cleavage surfaces: two basal cleavages covered with very distinct wide striations and one *i-ĭ*,

which is not polished, with very distinct striations running practically parallel to the edge between the base and *i-ĭ*. Were it not for the play of colors on *i-ĭ*, the striated brachy-pinacoid could not be told at a glance from the striated basal plane. How common such specimens are we cannot say; in the student's collection in the Boston Institute of Technology there are several specimens, probably all from one block, of exactly the same character. An analysis of this feldspar by Penfield is given below:

		Ratio.		Albite.	Anorthite.
SiO_2	54·75	·912		·528 (6) +	·384 (2)
Al_2O_3	27·76	·269	·273	·088 (1) +	·185 (0·97)
Fe_2O_3	·69	·004			
CaO	10·60	·189			·189 (0·98)
Na_2O	5·13	·083	·088	·088 (1)	
K_2O	·53	·005			
Ign.	·56				
	100·02				
Sp. gr.	2·684				

The ratio of anorthite to albite = 1 : 0·93 ; per cent of anorthite, 52·45. Rhombic section ± 0, extinction angle on *i-ĭ* = −19°. In this example the rhombic section, being parallel with the base, agrees very closely with the above table from Tschermak, where in andesine with Ab_1An_1, the rhombic section has the direction −2° and the extinction angle −16°.

The above analytical results give, therefore, a very satisfactory agreement both as regards the direction of the rhombic section and the extinction angle on *i-ĭ* with the tables given in Tschermak's Mineralogy. One other specimen in Professor Brush's collection (No. 1712), labeled anorthite from Mt. Somma, contains a fractured crystal with striations on *i-ĭ* inclined −13°. Although no material could be obtained for analysis, it is safe to assume that an analysis would show no, or only a very slight, percentage of Na_2O.

The variations in the angles of the plagioclase crystals is considerable, and, as vom Rath has shown, they affect the direction of the rhombic section very perceptibly ; however, the change in position of the rhombic section from +22° to −18 is so great that a careful consideration of the direction of the striations will enable one to decide within very narrow limits what position any plagioclase will hold in the albite-anorthite series.

In closing, we wish to express our thanks to Professor Geo. J. Brush for his liberality in allowing us to use the material from his collection for carrying out this investigation.

Mineralogical Laboratory, Sheffield Scientific School, June, 1887.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Production of Ozone from pure Oxygen.*—Having had occasion to prepare oxygen gas of a high degree of purity and to transfer it to experimental apparatus of various kinds without contamination, Shenstone and Cundall have taken the opportunity to study the conditions of the preparation of ozone from pure oxygen under the influence of the silent electric discharge. For the production and storage of the oxygen, the authors contrived a special form of apparatus made entirely of glass, the various parts of which are united by fusion. It consists essentially of a flask for generating the oxygen, containing a previously fused mixture of potassium and sodium chlorates in molecular proportions, and a cylinder of about a liter capacity, for storing it. To the right of this reservoir and to the left of the flask, connections are made with Sprengel pumps, glass taps of special construction being placed between. A third tap closes the tube between the flask and reservoir. At its lower end the storage cylinder is connected with a mercury reservoir, and sampling tubes are provided by which specimens of the gas may be obtained for examination. The precautions required in filling the reservoir are detailed in the paper. It was found that the most satisfactory reagent for determining the purity of the oxygen was phosphorus, and it was found possible by means of a special pipette, to avoid the introduction of any inpurity. So that after the absorption, not more than 1/5000 of residual gas remained. The authors believe however, that the purity of the oxygen actually exceeds this value. For the ozone experiments, the oxygen was collected in a glass cylinder, into the top of which the neck of a cylindrical bulb was fastened, the bulb projecting into the cylinder, leaving an annular space between the walls of the two. At its lower end the cylinder terminated in a smaller S-shaped tube upon which was a globe containing phosphoric oxide. Nine months after filling the apparatus with oxygen, the outer end of the S-shaped tube was broken off under sulphuric acid, the level of the liquid noted, and the enclosed gas electrified by connecting sulphuric acid placed in the cylindrical bulb, and a strip of tin foil opposite it on the outside of the glass cylinder, with the terminals of an induction coil capable of giving a four or five inch spark. A steady diminution in the volume of the gas set in, indicated by the rise of the acid in the S-shaped tube, until in the first experiment lasting 24 hours the contraction indicated that a conversion into ozone had taken place, of about 7·5 per cent of the oxygen employed. In a second experiment the gas was electrified at intervals for three days and the contraction indicated a conversion of 15 per cent of the oxygen into ozone. Doubting the accuracy of estimating the

amount of ozone formed from the contraction observed, the authors introduced some turpentine into the apparatus and noted the absorption. It amounted to about 11·7 per cent of the original volume of the oxygen. Another cylindrical tube provided as above with the cylindrical bulb and lateral reservoir containing phosphoric oxide, but also containing a small bulb of pure mercury, was filled with pure oxygen and electrified, and the bulb broken. The surface of the mercury lost its convexity and the mercury adhered strongly to the glass. In 24 hours, however, no signs of oxidation appeared on the mercury and after a few days it returned to its original condition, no trace of ozone being detectible within the apparatus. Hence the authors conclude that perfectly dry ozone is completely decomposed by mercury without oxidation of the metal. In order to study the character of the silent discharge, two strips of tin-foil were placed on the remote sides of sheets of patent plate glass, and these were mounted on the jaws of a small parallel vise, so that they could be moved to or from each other. At one centimeter distance, the discharge consists of a few noisy sparks. As they are approached the sparks diminish and the glow discharge increases, till at a millimeter, the glow greatly predominates. If now a little warm moist air be blown between the plates the glow vanishes, the discharge again consisting of a few large sparks. Hence it would appear that the high yield of ozone in dry oxygen is due to the fact that the condition of the interior surfaces of the apparatus are exceedingly favorable to the occurrence of the most efficient form of electric discharge.

In a subsequent paper, SHENSTONE and CUNDALL described a simple form of apparatus for showing as a lecture experiment, Loret's proof of the composition of ozone, which consists in submitting a fixed quantity of oxygen to the action of the electric discharge and of turpentine in succession and of observing the changes of volume which occur. A somewhat wide tube has the neck of a cylindrical bulb sealed into its upper end while its lower has two lateral openings, one of considerable size closed by a cork, the other connected to a tube passing vertically upward parallel to the large tube and closed with a tap. Near the top of the wide tube and on the opposite side is a re-curved tube filled with sulphuric acid colored by indigo, serving as a manometer. A bulb containing turpentine is introduced into the tube through the lateral tubulure, the apparatus is filled with oxygen, immersed in cold water, and the electric discharge passed between sulphuric acid contained in the cylindrical bulb and a strip of tin-foil on the outside of the main tube. The change of level in the liquid in the manometer shows the contraction. By shaking the apparatus the turpentine bulb is broken and the absorption of the ozone is effected.—*J. Chem. Soc.*, li, 610, 625, July, 1887. G. F. B.

2. *On the Density of Nitrogen dioxide and of Nitrogen tetroxide at* $-100°$.—In the hope that at very low temperatures, the unsaturated molecules NO and NO_2 dissociated at ordinary tempera-

tures would combine to form saturated molecules N_2O_2 and N_2O_4, Daccomo and Victor Meyer have submitted these gases to a temperature of −100°. By means of a simple apparatus, nitrogen tetroxide was exposed to a temperature in two experiments of −96° and −107° and its density was found to be the same as that possessed by it at ordinary temperatures. No evidence either of the existence of N_2O_2 at these temperatures was obtained; so that if this compound exists it is completely dissociated below this point. The apparatus used consisted of two exactly similar air thermometer bulbs, filled the one with air the other with nitrogen tetroxide. The liquid employed as a seal was sulphuric acid, the level being made exactly the same in both tubes. The bulbs were placed close together and covered with a mixture of solid carbon dioxide and ether. The contraction was exactly the same in both tubes, showing that the tetroxide had not changed its density.—*Ber. Berl. Chem. Ges.*, xx, 1832, June, 1887. G. F. B.

3. *On the Behavior of Phosphorus, Arsenic and Antimony at a white heat.*—Mensching and Victor Meyer have obtained evidence that phosphorus and arsenic suffer a marked loss of vapor density at a red heat and that at a white heat they approximate the values P_2 and As_2, although the densities corresponding to these molecules have not yet been observed. With regard to antimony, the authors have succeeded in determining its hitherto unknown vapor density, using a porcelain vessel. This element behaves in an entirely different way from phosphorus and arsenic, no molecular weight corresponding to the formula Sb_4 existing. On passing into the state of vapor, which it does with difficulty, it assumes at once a molecular condition represented by a formula smaller than Sb_4 and also than Sb_3. So that its actual molecular size is either Sb_2 or Sb_1, but which of these has not yet been determined owing to the difficulties of obtaining a normal antimony vapor having an invariable expansion-coefficient at this high temperature.—*Ber. Berl. Chem. Ges.*, xx, 1833, June, 1887.

G. F. B.

4. *On a Portable Apparatus for the rapid estimation of Carbon dioxide in air.*—On account of the importance for hygienic purposes, of rapid and accurate determinations of carbon dioxide in samples of air, Pettersen and Palmquist have devised a portable apparatus for this purpose with which in a few minutes the amount of CO_2 in a specimen of air can be determined to within 0·01 per cent. Referring to the original paper for an illustration and description of the apparatus, it may here be stated that each experiment consists of three distinct stages of operation. In the first the air to be examined is drawn into the apparatus, and measured. The cylindrical vessel in which it is contained has a capacity of 18^{cc}. It terminates below in a graduated scale tube, the lower part of which has a larger diameter than the upper, a mercury reservoir being connected to the lower end by a rubber tube. Above the measuring vessel is connected to a delicate

horizontal manometer. Each division of the upper portion of the scale tube corresponds to 1/10000 of the volume of this measuring pipette, each division of the lower portion to 1/1000 of this volume. The measurement is effected by adjusting the level of the mercury till the manometer index stands at zero and then reading off the volume on the scale. The second operation consists in transferring the air thus measured to an Orsat tube containing potassium hydrate and allowing it to remain one or two minutes to effect the absorption of the carbon dioxide. The third operation consists in returning it to the measuring pipette, adjusting the mercury to the manometric zero, and reading off the diminution of volume on the scale tube. For air containing up to 0·4 per cent of CO_2 the finer tube is employed; but for air more impure than this, the lower and larger scale tube is used. The results of measurements made with this apparatus compared with those given by Sondén's larger apparatus and by Pettenkofer's method are entirely satisfactory.—*Ber. Berl. Chem. Ges.*, xx, 2129, July, 1887. G. F. B.

5. *On the Atomic Weight of Silicon.*—The atomic weight of silicon which is usually employed rests upon two not very accordant determinations of the ratio of silicon tetrachloride to silver made by Dumas. THORPE and YOUNG have undertaken a new determination of this important constant, based on an estimation of the ratio of silicon tetrabromide to the silicon dioxide formed on treating the tetrabromide with water. The tetrabromide was prepared by passing bromine vapor over a strongly heated mixture of pure silica and finely ground willow charcoal such as is used in the manufacture of gunpowder. The rectified product was shaken with mercury, decanted, placed in contact with copper for some weeks and distilled in a current of dry nitrogen. It was absolutely clear and colorless and boiled constantly at 153°. Bulbs were filled with the tetrabromide without exposure to air, by the same method which was used by Thorpe for titanium. A bulb, containing a weighed quantity of the bromide, was placed in a well stoppered bottle with 10 times its weight of water, and broken by shaking. The turbid liquid was decanted into a tared crucible and evaporated over a water bath, an equal volume of water being evaporated under the same conditions in the tare. The two crucibles were dried in an air bath at 160°, then ignited in a muffle, allowed to cool and weighed by the method of vibration, employing all the necessary precautions. Nine separate determinations were made, giving values ranging from 28·243 to 28·429 as the atomic weight desired. The mean value obtained was 28·332, which the author adopts as the most probable value for the atomic weight of silicon.—*J. Chem. Soc.*, li, 576, June, 1887. G. F. B.

6. *On the Atomic Weight of Gold.*—THORPE and LAURIE have made a very careful re-determination of the atomic weight of gold, using for this purpose potassium brom-aurate, prepared by the action of pure bromine in excess upon pure gold

(999·88 fine by mint assay) in presence of an equivalent quantity of pure potassium bromide, and water. After three recrystallizations the salt was considered pure. An unweighed quantity, from 12 to 15 grams, was placed in a large porcelain crucible, previously weighed against a precisely similar crucible, and then heated for some hours at a temperature gradually increasing to about 160° after which it was still more strongly heated over a small Bunsen flame. The auric bromide is readily decomposed and the mixture of gold and potassium bromide is then weighed against the crucible used as a tare. Three ratios were made use of for fixing the atomic weight. The first was that of the gold to the potassium bromide, obtained by dissolving out the latter from the above mixture and weighing the remaining gold. The second ratio was that of the residual gold to the silver required to precipitate the bromine in the whole of the potassium bromide. And the third ratio was that of the residual gold to the silver bromide itself thus produced. All possible precautions were taken to secure accurate results. Eight determinations were made by the first method, the atomic weight varying between 196·85 and 196·90. Nine determinations by the second method gave values varying from 196·78 to 196·90. Eight estimations by the third method gave 196·77 as a minimum and 196·91 as a maximum value. But it is better to deduce the final results from the aggregate weights of the gold, potassium bromide, silver and silver bromide. The mean of the first series thus calculated is 196·876; of the second 196·837; and of the third 196·842. The mean of these values is 196·852, with a probable error of ±0·0082. This the authors consider to be the atomic weight of gold.—*J. Chem. Soc.*, li, 565, June, 1887. G. F. B.

7. *On the Occurrence of Alkaloïd-like Bases in Paraffin Oil.*—WELLER has called attention to the occurrence of basic bodies resembling the alkaloids in a yellow paraffin oil of sp. gr. 0·850 to 0·860, obtained as a bye-product in the Saxony paraffin works. To obtain these bases 500 kilograms of this paraffin oil were agitated with dilute sulphuric acid, the acid decanted, mixed with soda solution and agitated with ether; the operation being several times repeated. A dark brown oily residue was left after distilling off the ether which gave on distillation in a current of steam a colorless oil of 0·98 to 0·99 specific gravity and having an intense disagreeable odor, mouldy when cold and recalling pyridine when heated. This oil contained nitrogen but neither sulphur nor oxygen, and distilled unchanged between 220° and 260°. Ammonium oxalate precipitates its solution in hydrogen chloride, the precipitate being white and crystalline. By saturating an alcoholic solution of the bases with oxalic acid, the oxalate is obtained first in fine needles which rapidly increase to large plates, extending through the solution. After recrystallization, the crystals are pearly in luster and have a fatty feel, and are soluble in hot water.—*Ber. Berl. Chem. Ges.*, xx, 2097, July, 1887.

G. F. B.

8. *Photography applied to the flight of birds.*—M. MAREY continues his researches upon this subject and shows that his method of taking photographs of the flight of a bird on a horizontal and also on a vertical plane enables one to reproduce the phenomenon of flight in a zoetrope, and also to study the mechanism of flight. He shows that previous observers have greatly exaggerated the rise and fall of a bird's body during flight.—*Comptes Rendus*, Sept. 5, 1887, p. 422. J. T.

9. *Spectra of Hydrogen, Oxygen and Water Vapor.*—Professor GRÜNWALD of Prague enunciates the following theory of the relationship of the spectra of gases and their compounds. Let $[a]$ be the volume occupied by a primary chemical element, a in the unit of volume of a gaseous substance, A. Let A be chemically combined with a second gaseous body, B, to form a third, C. The element a now takes the form a' and the volume $[a']$. Then the wave lengths, λ, of the lines in the spectrum of A, which belong to a, are to the wave lengths, λ', of the lines in the spectrum of C, which belong to a', as $[a]$ is to $[a']$. The wave lengths of the elementary spectrum of hydrogen can be arranged into two groups, a and b, which give the lines of the water vapor spectrum when they are respectively multiplied by $\frac{19}{30}$ and $\frac{4}{5}$. The author concludes that hydrogen is composed of the combination of four volumes of the element a with one of the element b. The first element, a, should be the lightest of gases and lighter than hydrogen. Since it must therefore enter into the constitution of the corona, Professor Grünwald calls it coronium. The D_3 or helium line is found in the spectrum of the element b, and the author therefore calls b the helium line. The correspondence between the wave lengths calculated by this theory and those actually observed is striking.—*Phil. Mag.*, Oct., 1887, p. 354. J. T.

10. *Earth currents.*—M. LANDERER gives, as the result of his observations during the past nine years, that, on the special line employed by him, the general direction of currents is from south to north. If the frequency of the currents from northeast to southeast be denoted by 1, that of currents in the opposite direction will be 6·7. The maximum intensity occurred about 10 A. M.—*Comptes Rendus*, Sept. 12, 1887, p. 463. J. T.

11. *Electrical standards.*—A committee of the British Association upon this subject submitted, at the late meeting at Manchester, the following resolutions: "1. To adopt for a term of ten years the legal ohm of the Paris Congress as a legalized standard sufficiently near to the absolute ohm for commercial purposes. 2. That at the end of the ten years period the legal ohm should be defined to a closer approximation to the absolute ohm. 3. That the resolutions of the Paris Congress with respect to the Ampère, the Volt, the Coulomb, and the Farad be adopted. 4. That the resistance standards belonging to the committee of the British Association or electrical standard now deposited at the Cavendish Laboratory at Cambridge be accepted as the English legal standards, conformable to the adopted definition of the

Paris Congress." The committee also recommend the adoption of the Watt as the unit of power. "The Wått is defined as the work done per second by the Ampère passing between two points between which the difference of electric potential is one Volt."—*Nature*, Sept. 22, 1887, p. 498. J. T.

12. *Absolute wave lengths.*—From a careful comparison of the observations of Pierre, of Kurlbaum and his own, Mr. L. BELL concludes that the wave length of D is very near to 5896, and consequently all wave lengths based upon Ångström's value are incorrect by at least one part in 8000. Ångström's relative wave lengths are also inexact.—*Nature*, Sept. 29, 1887, p. 524. J. T.

13. *Annalen der Physik und Chemie*, No. 9, for 1887, contains the following articles:

An investigation on a jet of steam, by R. v. HELMHOLTZ. The author shows the influence of certain substances in forming clouds of vapor by means of the steam. He also discusses the behavior of the jet under electrical influences. The action of finely divided particles in forming clouds is commented upon.

On electrical residual charges and induction in dialectrics, by A. WÜLLNER.

The Contact Theory, by FRANZ EXNER. The author tries an experiment to disprove the theory.

Upon the theory of an experiment by F. Exner on the Contact Theory, by WILHELM HALLWACHS. The author exposes an error made by F. Exner.

On the development of Electricity by the friction of drops of liquid, by JULIUS ELSTER and HANS GEITEL. This is a careful repetition of Faraday's experiment, with certain amplifications.

Electrical polarity of Rock crystal, by W. HANKEL.

Resistance of Selenium when exposed to light, by S. KALISCHER. This paper contains various measurements of specimens of selenium.

Electrolytic separation of metals at the free surface of a solution of a salt, by Dr. J. GUBKIN.

Galvanic Polarization, by FRANZ STREINTZ. This is a careful study of the relation of the oxygen and hydrogen polarization to the polarizing current.

Electrical conveyance of heat, by H. HAGA. This is an answer to objections raised by Budde against the author's work.

Magnetization formula, by A. VON WALTENHOFEN.

Electromagnetic rotation phenomena in fluid conductors, by F. SCHUMANN.

Separation of white light into complementary colors, by W. VON BEZOLD. This is a lecture-room experiment, the main feature of which is the employment of a prism and a cylindrical lens.

Optical peculiarities of certain chemical compounds. This is a study of the absorption spectra of certain organic compounds, with reference to the constitution of the compounds.

Experimental investigation upon rotating fluids, by W. VON BEZOLD. This investigation bears upon the theory of cyclones and tornadoes.

Designation of the mass system, by L. PFAUNDLER.

On a new form of galvanic battery, by F. FRIEDRICHS. By an attachment similar to the mercury vessel employed in the Toepler air pump, the author regulates the height of liquid in a series of galvanic cells. J. T.

14. *On Pritchard's Wedge Photometer.**—The photometer devised by Professor Pritchard, consists of a wedge of neutral glass which is inserted between the observer's eye and the eye piece of the telescope and moved along until the thickness is sufficient to render a given star invisible. An instrument of this kind has been successfully used in obtaining the measures of the light of the stars given in the Uranometria Oxoniensis. In order to test its value and accuracy some observations have been recently made by Professors Young, Langley and Pickering. The former makes some practical remarks in regard to the ease and convenience of its use based upon the results obtained upon six stars in the neighborhood of γ Pegasi and gives estimates of the probable error in the determination of magnitude. He states that the method is much more wearisome to the eye than those involving the equalization of the light as in the double image photometers.

Professor Langley investigated the wedge by means of the bolometer and found that there was a distinct selective absorption throughout the wedge, even in the visible rays; this was feeble in the more luminous part of the spectrum but such that the transmissibility increased from the violet toward the red, and still more beyond the red. In order to decide the question as to the influence of this selective absorption upon the value of the instrument for photometric work, Professor Pickering made a series of measurements with it at the Harvard Observatory and added to these some photographs of the solar spectrum through it. The photometric measures failed to show the gradual diminution in the coefficient of absorption as the thickness increased. The photographs, however, showed that the intensity of the spectrum transmitted fell off rapidly, beyond $\lambda=0{\cdot}41$ becoming entirely invisible at $\lambda=0{\cdot}40$. The opacity of the wedge increased rapidly as the wave-length diminishes, as the bolometer showed. The conclusion is reached that, though valuable results may be obtained by the wedge photometer when skillfully used, the observations show sources of error needing careful study before it can safely be applied to stars of different colors, or to detecting small systematic errors in the star catalogues.

15. *On the Beneficial Effects of Light;* by G. G. STOKES. 100 pp. 12mo. London and New York, 1887. (Macmillan & Co.).—This volume contains four lectures delivered as the third course of Burnett lectures at Aberdeen in November, 1885. They deal with topics which are readily understood and are presented in a simple and agreeable style. They will be enjoyed now in permanent form by a larger audience than that before which they were presented.

* Investigations on Light and Heat, published with appropriation from the Rumford Fund.

II. Geology and Mineralogy.

1. *The Terminal Moraines of the Great Glaciers of England;* by Professor H. Carvill Lewis.—The investigation here recorded is based upon the important principle that *every glacier at the time of its greatest extension is bounded and limited by a terminal moraine.* Supposed exceptions to this law in Switzerland and elsewhere had been studied by the author and found to be contrary to observed facts. Thus the ancient Rhone glacier, stated by Swiss geologists to be without a limiting moraine at the time of its greatest extension, was found to have one as distinct as those of the Aar glacier, the Reuss glacier, or the Rhine glacier; and the prevalent idea of a "first glacial epoch" in which the glaciers had no terminal moraines was also unsupported by the author's observations.

The great ice-sheet which once covered northern England was found to be composed of a number of glaciers, each of which was bounded by its own lateral and terminal moraines. These glaciers were studied in detail, beginning with the east of England; and the North Sea glacier, the Wensleydale glacier, the Stainmoor glacier, the Aire glacier, the Irish Sea glacier, and the separate Welsh glaciers were each found to be distinguished by characteristic bowlders and to be defined by well-marked moraines. The terminal moraine of the North Sea glacier, filled with Norwegian bowlders, may be seen in Holderness extending from the mouth of the Humber to Flamborough Head, and consists of a series of conical hills enclosing meres. The moraine of the Stainmoor glacier, characterized by blocks of Shap granite, may be followed northward along the coast past Scarborough and Whitby; then west along the Cleveland Hills; then south again through Oulston to the city of York; then west to near Allerton, where the Stainmoor glacier is joined by the Wensleydale glacier—a fine medial moraine marking the line of junction. The Wensleydale glacier is characterized by bowlders of Carboniferous limestone and sandstone, and its lateral moraine is followed northward through Wornald Green, Markington, Fountains Abbey, and along the Permian outcrop to Masham, where it turns west to Wensleydale, passing Jervaulx Abbey, and running up the valley. North of Wensleydale the moraine of the Stainmoor glacier is followed through Richmond to Kirkby Ravensworth and westward to the mountains, where the glacier attained an elevation of 2,000 feet. Thus the Stainmoor glacier, a tongue of the great Irish Sea glacier, had been divided into two branches by the Cleveland Hills, one branch going south to the city of York, which is built on its terminal moraine, the other branch flowing out of the Tees and being deflected southward along the coast by the North Sea glacier, with which it became confluent.

The Irish Sea glacier, the most important glacier of England, came down from Scotland, and, being reinforced by local ice-

streams, and flowing southward until it abutted against the mountains of Wales, was divided into two tongues, one of which flowed to Wellington and Shrewsbury, while the other went southwest across Anglesey into the Irish Sea. This great glacier and its branches are all outlined by terminal moraines, described in detail. A small tongue from it, the Aire glacier, was forced eastward at Skipton and has its own distinctive moraine. In the neighborhood of Manchester the great moraine of this Irish Sea glacier may be followed through Bacup, Hey, Staley Bridge, Stockport and Macclesfield, being as finely developed as the moraines of Switzerland and America. South of Manchester, it contains flints and shell-fragments, brought by the glacier from the sea-bottom over which it passed. At Manchester the ice was at least 1,400 feet thick, being as thick as the Rhone glacier.

The great terminal moraine now described of the united glaciers of England is a very sinuous line, 550 miles in length, extending from the mouth of the Humber to the farthest extremity of Carnarvonshire, and, except where it separates the Welsh glaciers from the North Sea glacier, everywhere marks the extreme limit of glaciation in England and is an important feature which might well hereafter be marked on the geological map of England.

2. *Les Eaux Souterraines a l' époque actuelle;* Leur régime, leur température, leur composition au point de vue du rôle qui leur revient dans l' économie de l' écorce terrestre; par A. Daubrée. Membre de l' Institut. 2 vols. of 456 and 302 pages, 8vo. Paris, 1887. (Vve. Ch. Dunod.)

Les Eaux Souterraines aux époques Anciennes; Rôle qui leur revient dans l'origine et les modifications de la substance de l'écorce terrestre; par A. Daubrée. 483 pp. 8vo, Paris, 1887. (Vve. Ch. Dunod.)

These new works, by the eminent physical geologist of France, M. Daubrée, bear on some of the most interesting of geological questions, and at the same time treat of subjects of wide economical importance. In the first of the two, the existing subterranean waters considered by the author are those of wells, river sources, caverns, artesian wells, saline waters, and mineral springs of various kinds. The relations of wells and water sources to permeable and impermeable strata are illustrated from special facts with regard to superficial deposits, taken in part from the suburbs of various cities, especially those of Europe and Great Britain; and also with a similarly wide range of facts, the author treats of their dependence on the systems of fissures in rocks; on the junction planes of different rocks; their relations to rocks of different kinds, and of different geological periods; their connection with the making of caverns; their emergence as full-made rivers from caverns; their ejection from borings by different gases. The discussion of these various subjects occupy the first volume of 456 pages. The second treats in a general way, without an array of chemical analyses, of the substances held in solution by waters;

their action in the production and alterations of minerals; the relation of subterranean waters to the constitution of the soil, and to temperature; and on geysers and their relations to volcanoes and earthquakes. The work is rich in facts, and contains among its many illustrations very fine copies of photographs, as the "Cascade del Marmore" above Terni; the "Cascades and Cascatelles" of Tivoli, near Rome over travertine deposits; the Beehive Geyser, from one of the photographs of Hayden's expedition; the source of the Fontaine de Vaucluse, in Southern France; a landscape with calcareous incrustations at the source of the Clouange in German Lorraine, etc.; also numerous wood cuts.

The second of the two works has for its subject, as stated on the title page, the part which the older waters have performed in the origin and modification of the rock-material of the earth's surface. The results of the author's investigations with regard to the origin of minerals from subterranean waters and by means of laboratory experiments, described at length in his former invaluable work on Experimental Geology, are here brought forward, along with others, in a general review of the agency of subterranean waters in mineral-making and rock-alteration; the special subjects being the agency of waters in connection with the origin of the minerals of amygdules; of metalliferous deposits and veins; of concretions; of pseudomorphic and metamorphic changes, both as regards composition and structure (the latter including schistosity); and of some of the deposits making the stratified rocks of the globe, questioning whether all the salt deposits of the rocks are of marine origin, and all the limestone and dolomite of organic derivation. The view is sustained and demonstrated that water has been concerned in nearly all the vein-making, and the alterations that have gone forward, and is, therefore, the "mineralisateur par excellence" of geological time. The volume is handsomely illustrated, and contains many figures from the author's former work.

3. *The Connecticut Lake of the Champlain period, north of Holyoke.*—Prof. B. K. Emerson thus describes the lake in the Connecticut valley, made from the melting glacier in the vicinity of Amherst, in a paper on Hampshire County, Mass.:

"Upon the disappearance of the ice from this section of the valley, the great volume of the waters of its melting sustained a lake, which stretched in width to the full limits of the valley, as we have give them, in length from Mt. Toby to the foot of Holyoke, and sent a broad lobe out around Mt. Tom, across Easthampton and Southampton, and on south. Its height was 300 feet above the sea and 200 above low water of the present Connecticut.

The Long Plain in Leverett, North Amherst station, the Bay road, the south spur of Mount Warner, the Florence plain, and West Farms, are level portions of its shore flats. The first and last two are great deltas sent out into its waters. In all its deeper waters the flat, laminated clays were being deposited, while the sands of the deltas were extending out from the shore.

Each layer of the clay, on an average of two-fifths of an inch thick, represents a year's deposit. The clays are, at the Northampton bridge, above 120 feet thick, and at East Street bridge above fifty feet, which would give numbers for the duration of the lake favoring the idea that the Glacial period was not more than 10,000 years ago, one of the shortest estimates.

In these clays I have found an abundant glacial flora, proving that the lake succeeded immediately to the ice, and I have found indications of several re-advances of the ice ploughing up the sands of the lake."

4. *Geological work of Marmots.*—Professor MUSHKETOFF's account of his explorations in the Caspian steppes contains some interesting remarks on the work done by marmots (*Spermophylus Eversmanii*) in the modification of the surface of the steppe. They made their appearance in the region only a few years ago, but their heaps of earth already cover hundreds of square miles. Like earthworms, they must therefore be regarded as a factor of some importance in modifying the surface of the soil. Their heaps of earth have an average length of $3\frac{1}{2}$ meters, and a width of $2\frac{1}{2}$ meters, with an average height of from 30 to 50 centimeters, and it was found that on each 2 square meters there were no less than five, seven or even eight heaps, each of which represented at least 2 cubic meters of earth removed. It may be safely asserted that on each square kilometer of surface no less than 30,000 cubic meters of earth have been brought to the surface owing to their activity. Their influence on vegetation is also well worthy of notice.—*Nature*, Oct. 6, p. 541.

5. *Slide at Lake Zug of July*, 1887.—On July 5, 1887, at the town of Zug, in Switzerland, a portion of the shore gave way and sank into the lake. About three hours later another much larger adjacent area also suddenly subsided, so that in all an area considerably over two acres, with half of one of the principal streets, was submerged to a depth of about 20 feet. It can be seen that the subsoil consists of coarse gravel and sand, followed after a few feet by soft wet sand and fine mud. According to Professor Heim, this fine mud or sludge reaches to a depth of nearly 200 feet, and the disaster is shown to be due to a flowing out into the lake of this mobile sludge from under the superincumbent weight of buildings and firmer ground. The buildings collapsed as they sank. The catastrophe must have been long impending; the exact cause which precipitated it is undetermined, but a low level of the lake and tremors from pile-driving for new quays are suggested as contributories.—*Geol. Mag.*, Oct., 1887.

6. *Organic origin of Chert.*—Dr. G. J. HINDE has a paper in the Geological Magazine, for October, showing conclusively that the chert from the Carboniferous limestones of Ireland was all made chiefly from the siliceous spicules of sponges, and that the silica of silicified fossils has the same source.

7. *A sketch of Geological History, being the Natural History of the Earth and of its prehuman inhabitants*; by EDWARD

Hull, F.R.S., Director of the Geological Survey of Ireland. 18 pp., 12mo, with an illustrative diagram. London, 1887 (C. W. Deacon & Co.).—This work is a very brief sketch of geological history, giving the chief facts in small compass, without illustrations.

8. *The so-called Harlem Indicolite;* by R. B. Riggs. (Communicated.)—Some time since a peculiarly bright blue mineral, found at Harlem, N. Y., was sent to the National Museum by Mr. H. D. M. Fair, of Sing Sing, N. Y., for identification. It occurs in slight columnar crystals, in a quartz-feldspar rock abounding in the more or less disintegrated quartz. Is infusible, but loses color on being ignited. It is of rare occurrence and material sufficient for analysis was not at first to be had. The finding of boric acid, however, leads to the conclusion that the mineral was a rare variety of tourmaline. In studying the tourmaline my attention was called to it, and thinking that a partial analysis, at least, might be desirable, something over a gram of quite pure material was finally obtained. The analysis, as follows, at once revealed relations very different from those existing in tourmaline:

	SiO_2	B_2O_3*	Al_2O_3	MgO	Na_2O	K_2O	Ign.	
	34·82	4·07	55·30	0·57	1·76	1·04	2·96,	Fe_2O_3, CaO, Li_2O *tr.* = 100·52
Ratio	·580	·058	·054	----	·029	·011	·165	

Through the kindness of Mr. G. F. Kunz additional material, sufficient for certain determinations made in duplicate, was obtained. The molecular ratios, deduced from the analysis, are very closely expressed by the formula

$$3(H_2O).(Na,K)_2O.10(Al_2O_3).10(SiO_2)B_2O_3$$

a new boro-silicate. The question of the purity of material analyzed is ever an important one. From the nature of the case it is probable that we have something new to deal with. Impurities coming from either the associated quartz or feldspar would tend to increase the silica and lower the alumina ratios, and that very materially.

That this blue mineral is not tourmaline was also made evident by the microscopic study very kindly made by Mr. J. S. Diller, who, with but little material at his disposal, was nevertheless able to make the following observations. "It is undoubtedly biaxial with remarkable pleochroism, (*c*) ultra-marine, (*b*) reddish violet, (*a*) colorless. The angle of extinction is very small, the largest observed being 8°. Its structure is sub-fibrous, so as to render somewhat obscure the angle of prismatic cleavage."

That this so-called indicolite is not such is certain, that it is a new boro-silicate is highly probable.

Chem. Lab. U. S. G. S., Washington, Aug. 31, 1887.

9. *Notes on some Mineral localities in Litchfield, Conn.;* by M. R. Gaines.—The following observations on the occurrence of washingtonite "in place" in the town of Litchfield, Conn., were

* Mean of two determinations 3·83, 4·31.

made during the writer's residence there between 1872 and 1879. The crystals of washingtonite found were of the ordinary type, flattened hexagonal prisms, with the alternate angles replaced by rhombohedral planes. A. (1.) On the west side of the Wolcottville road, about two miles northeast of the village of Litchfield, is the "Yale Farm," which extends back to the crest of the ridge running north and south. At some distance down the eastern slope of this ridge, a mass of white quartz rock can be seen standing out conspicuously in the open field. Fine crystals of washingtonite were found in this mass itself as also in the blocks on the slope below that had fallen from it. (2.) On the adjoining farm to the south, owned by a Mr. Smith, near the top of the same ridge, beside a cart path leading up to a small cultivated field, the mica schist crops out in a small grove of hickory trees. Here a number of plates of washingtonite, without well defined angles, were found in the rock, associated with well preserved crystals of staurolite of a dark brown color.

B. Just east of the village of Litchfield below the point where the road to the Naugatuck station crosses the Bantam river, there is a mill dam, the abutment at the western end of which is formed by a ledge of mica schist. Here were found fine crystals of pinite, and in quartz veins a few fine specimens of washingtonite. C. The stage road to the Litchfield station on the Naugatuck railroad, crosses Cedar brook at East Litchfield; from this point looking south a bold rocky peak is visible rising abruptly from a narrow valley on the right bank of the stream, which can be easily reached by the wagon road running south. From a farm house on the road to the southwest of the peak, a path runs to the northeast through the fields and woods on the south side. About a hundred and fifty rods from this house, in the mica schist which is transversed by large veins of quartz, were found several crystals of staurolite of unusual size, and also masses of iron ore that proved to be portions of very large crystals of washingtonite. One or two blasts brought to view one perfect crystal of washingtonite, imbedded in the quartz, that measured nearly seven inches in its longest diameter. It fell to pieces when an attempt was made to extract it but the whole crystal must have weighed about six pounds.

Kyoto, Japan, May 20, 1887.

10. *Analysis of Blue Clay from Farmington, Maine;* by F. C. Robinson (communicated).—The following analysis of clay was made in my laboratory by Mr. W. V. Wentworth, and may be of interest for reference, especially as I found but few such analyses recorded when I recently had occasion to look up the subject.

SiO_2	63·69
Al_2O_3	17·02
FeO and Fe_2O_3 (mostly FeO)	10·18
CaO	·97
Na_2O	4·02
H_2O	4·05
	99·93

An approximate mechanical analysis gave the following results:

Coarse sand	3·73	per cent.
Fine sand	22·97	
Fine clay	69·25	
Water	4·05	
	100·00	

The sand was mostly feldspar with traces of quartz and mica. The clay is used for brick making.

11. *Magnetite crystals pseudomorph after pyrite;* by G. C. HOFFMANN. (Communicated).—A short time back I had sent me for analysis a sample of iron ore from a deposit which occurs in the vicinity of Kinnear's Mills, township of Leeds, Megantic County, Province of Quebec. It consisted of a very fine crystalline magnetite and hematite (the former preponderating), through which was disseminated a large amount of siliceous gangue. Numerous small patches of limonite occurred, interspersed, through the ore, apparently resulting from the decomposition of the pyrites, and there was also a little unaltered pyrite. My assistant, Mr. E. B. Kensick, has made the following observations in regard to some small crystals imbedded in this ore.

The crystals were in the form of small cubes with faces striated parallel to the edges of the pyritohedron. They were black in color and showed a high metallic luster and brilliant faces. The best crystals had cubic edges measuring 1^{mm} or less in length. The crystals were very magnetic, being easily picked up with a magnet. Streak brown. Soluble in aqua regia with very slight residue. Gave off water in closed tube. A crystal weighing ·0083 gram lost on ignition ·0008 gram, or 8·6 per cent of water. This crystal was magnetic after ignition and remained unchanged in appearance. It would appear that the crystals are pseudomorphs after iron pyrites in an intermediate stage between limonite and magnetite.

12. *Anwendung der Linearprojection zum Berechnen der Krystalle von* DR. MARTIN WEBSKY. 377 pp. 8vo, with 11 plates. Berlin, 1887, (E. S. Mittler & Sohn).—A peculiar interest attaches to this work in that it was issued after the death of its gifted author; the final supervision has been given by Dr. C. A. Tenne. It is intended to form the third volume of Rose's *Elemente der Krystallographie*, a fourth volume in which series was projected by the same author and in part completed. It contains an exhaustive treatment of the principles and methods of the system of crystallography founded by Weiss and developed by Rose and Quenstedt. Whether this system is the one which, as most convenient of use, is likely to be generally adopted would seem doubtful. It is, however, a great advantage to the students in this line to have the whole subject presented in a manner which, as regards clearness and completeness, meets every requirement. Numerous examples, worked out in all possible fullness, enable the student to go forward without a teacher's assistance.

III. Botany and Zoology.

1. *Annals of Botany;* edited by Isaac Bayley Balfour, Sidney Howard Vines, and William Gilson Farlow. Oxford, Clarendon Press, vol. I, no. 1, August, 1887.—The character of this welcome journal will be understood when we say that it is worthy of the press from which it comes. The typography and the illustrations leave nothing to be desired; they place the journal on an equality with *Annales des Sciences Naturelles* (*Botanique*) and Pringsheim's *Jahrbücher.* The letterpress is in some respects superior to that of either of the periodicals mentioned and the plates are in every way as good.

The scope of the Annals is wide enough: "Original papers, adequately illustrated, are to be published from time to time, on subjects pertaining to all branches of botanical science, including Morphology, Histology, Physiology, Palæobotany, Pathology, Geographical Distribution, Economic Botany, and Systematic Botany and Classification."

The first number has a preponderance of histology, the four leading articles being devoted to special studies in minute structure, with incidental reference to physiological points. The articles are substantial contributions to our knowledge of the structures, and are of the kind with which readers of Pringsheim, the French Annales, and of Botanische Zeitung are familiar.

Then follow five minor notes, all of interest and two of them of importance. Here again, histology has rather the lion's share. Next, eight pages are given to a laudatory and yet very discriminating criticism of the English edition of Sach's Lectures on the Physiology of Plants. The reviewer has succeeded in accomplishing just what Dr. Gray has so often done in the pages of this Journal, namely, has shown each reader whether the book under review is the sort of a book which he needs. If the reviews in future numbers can be as comprehensive without prolixity, and as critical without faultfinding as this review of Sachs's work is, we may say that no English-speaking student of botany can afford to be without the Annals.

Forty pages are given up to an enumeration of the books and pamphlets, and of the periodical literature of the science. Although the *Centralblatt* and some other periodicals place these titles before us with more or less completeness, in no journal of our acquaintance do they appear in so convenient a form. Such lists are always useful, but in this instance are rather disappointing, for besides the title there is no hint of the character or even of the length of the paper. It is a pleasure to note the significant fact that one of the editors is an American. During the last few years there has been considerable increase in interest in this country in many botanical subjects other than those which belong to the determination of Phanerogams. It is fitting that an American representative of this interest should participate in the conduct of the new journal. Moreover, Professor Farlow possesses the critical faculty in a high degree, and will see well to it that con-

tributions from this side of the water are no discredit to a journal which starts out so fairly. G. L. G.

2. *Dermatitis venenata;* by JAMES C. WHITE, M.D., Boston, 1887, 8vo, 216 pp.—Professor White has brought together in this treatise a great amount of interesting information of an important character. Restricting this notice to the botanical portion of the work, we may say that the results here presented are altogether surprising. Everyone knows that we have, for instance in the New England States, a few plants which are either poisonous or merely irritant to the skin, such as the two dreaded species of Rhus, one or two nettles and the like. But we confess to a feeling of insecurity when we are informed that the following plants are justly regarded as poisonous to the human skin: Water-plantain, May-apple, Fleabane, Ox-eye Daisy, Mayweed, Golden-rod, Arbor vitae, House-leek, Sundew, Prince's Pine, Asparagus, Flax, Ladies' Slipper, Blood-root, Garget, Monkshood, Baneberry, Wind-flower, Clematis, Larkspur, Buttercups, Mullein, Moose-wood, and even Balm of Gilead. Concerning these common plants and many others, Professor White has brought a formidable indictment sustained by evidence. The whole work is marked by great patience in collecting and sifting testimony from all quarters, and affords a mass of facts for the use of the biologist, as well as the practitioner of medicines. G. L. G.

3. *Lectures on the Physiology of Plants;* by JULIUS VON SACHS, Translated by H. MARSHALL WARD, M.A., F.L.S. Oxford, at the Clarendon Press, 1887, 8vo, 836 pp.—The German edition of these lectures has been already noticed in this Journal; attention was then called to the wide range of subjects treated, to the interesting manner of stating important points, and to the desirability of having the work soon placed before English readers. The translation before us is exceptionally successful. The ideas have been carried over into the English language and not merely into English words. To accomplish this the translator has taken the course which was followed in the preparation of two French translations of previous works by Sachs; whole sentences have been reconstructed, leaving scarcely a trace of the original phrase but never with any sacrifice of the author's meaning. To those who read this work it must be frankly said, that they are presented with certain physiological questions as Sachs sees them, and frequently without any distinct reference to the fact that many of them have two sides. If this treatise is read in conjunction with Vines's Physiology, the student will be placed in possession of the most trustworthy statements of the principles of vegetable physiology. And every reader will rise from his perusal of the two works with the feeling that the two writers have been discriminating in the selection of material, and that both have kept steadily in mind the accepted aphorism, cited by Sachs in his preface,—"the secret of being tedious lies in trying to say all one knows." These two writers have said just about enough in their treatises, and have completely escaped the charge of being tedious. G. L. G.

4. *Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria;* by A. DEBARY, Professor in the University of Strassburg, Translated by H. E. F. GARNSEY, M.A., Revised by ISAAC BAYLEY BALFOUR, M.A., M.D., F.R.S., Professor of Botany in the University of Oxford. Oxford, at the Clarendon Press, 1887, 8vo, 525 pp.—This translation affords gratifying proof of the strong hold which questions bearing on the structure and life of plants have lately acquired among English-speaking people. A few years ago, no publishing house would have been willing to hazard a publication like the present; the demand for such a treatise would have been confined to specialists and to a few teachers who probably could have made equally good use of the original. But, now, such a volume meets with a considerable sale, even on this side of the Atlantic.

From the good degree of prominence which the author gives to the phenomena presented by these lowest vegetable organisms, the work is of great interest to everyone who is attracted to the study of physiology, and we may also say to pathology. When it is remembered how important a part the organisms last mentioned in the title play in health and disease, we cannot be too grateful that so sound a treatise has been offered to medical students in so attractive a form. As will be noticed in the title above given, those organisms of uncertain place, termed in most of our recent botanical works, Myxomycetes, are treated under the better name of Mycetozoa.

The translation is good throughout, and the choice of technical English equivalents for German scientific terms has been, for the most part, judicious. The translation of such a work as this must hasten the time when there will be some convention with regard to English terminology applied to the morphology of Cryptogams. Such convention would doubtless have due respect to certain prior claims held by the morphology of phanerogams, and which are nowadays somewhat ignored. It is proper that we should express our feeling of obligation to the English press which has given to our students within a short time five volumes of great excellence. G. L. G.

5. *Journal of Morphology;* edited by C. O. WHITMAN, with the co-operation of EDWARD PHELPS ALLIS, JR., Milwaukee. Vol. I, No. 1, Sept., 1887. 226 pp., 8vo, with several plates. Published by Ginn & Co., Boston, at six dollars a year.—This new journal, devoted principally to embryological, anatomical, and histological subjects, comes into existence with all those high qualities as regards grade of scientific memoirs, beauty, fullness of illustrations, paper, typography, and generous capacity that we usually look for as the characteristics of slowly developed and successful maturity. It shows confidence in the scientific spirit of the country by placing itself at once on a level with the journals of the kind abroad, and well merits the success it looks for. Although its active editors are at Milwaukee in Wisconsin, the contributors to this number are from various parts

of the country: Toronto, Canada, the State University of Indiana, Yale College in Connecticut, Bryn Mawr College in Pennsylvania, besides Milwaukee, showing thus its continental sympathies, purpose and demands. Its papers are as follows: (1) Sphyranura Osleri, a contribution to American Helminthology by R. R. Wright and A. B. Macallum, of Toronto; (2) Development of the compound eyes of Crangon, by Dr. J. S. Kingsley, of Indiana; (3 and 7) Eyes of Molluscs and Arthropods, and Development of the eyes of Vespa, with observations on the ocelli of some insects, by Dr. Wm. Patten, of Milwaukee; (4) Phylogenetic arrangement of the Sauropsida, by Dr. G. Baur, Yale College Mus.; (5) Contribution to the history of the Germ-layers in Clepsine, by C. O. Whitman, of Milwaukee; (6) The Germ-bands of Lumbricus, by Prof. E. B. Wilson, of Bryn Mawr, Pa.

The second number will probably be issued in November.

6. *Bibliotheca Zoologica* II: Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861–1880 selbstandig erschienen sind, etc., bearbeitet von Dr. O. Taschenberg. Lieferung III, pp. 641–960. Leipzig, 1887 (Wm. Engelmann).—The nature and scope of this great catalogue of zoological works have been explained in this Journal (vol. xxxiii, 245) in connection with a notice of parts 1 and 2 of the first volume. The part now issued concludes volume I, and continues the exhaustive method before noted. It is a work which should be at the hand of every one laboring in the various subjects which it embraces.

IV. Miscellaneous Scientific Intelligence.

1. *Nystrom's Pocket Book of Mechanics and Engineering.* 19th edition, revised and corrected by W. D. Marks. 670 pp. Philadelphia, 1887 (J. B. Lippincott Company).—This volume is truly remarkable for the variety and extent of the information it contains. No one who has learned by experience the value of having such an assistant at hand will be willing to be without it. The present edition has had the benefit of revision by Professor Marks which commends it to a still wider circle of readers.

2. *Sixth Annual Report of the U. S. Geological Survey*, by J. W. Powell, Director, 1884–85.—Of the papers published in this report, Mount Taylor and Zuñi Plateau, by Capt. C. E. Dutton, has been already noticed in this Journal. The others are "Preliminary papers on the driftless area of the Upper Mississippi valey, by T. C. Chamberlin and R. D. Salisbury, pp. 199 to 352; Preliminary report on Sea-coast Swamps of the Eastern United States, by N. S. Shaler, pp. 359 to 398, and Synopsis of the Flora of the Laramie Group, by Lester F. Ward, pp. 399 to 558, illustrated by 65 double plates representing fossil leaves.

3. Dr. Wolcott Gibbs has resigned the Rumford Professorship in Harvard University, and will continue his scientific work at Newport, R. I.

APPENDIX.

ART. XLV.—*Principal Characters of American Jurassic Dinosaurs.* Part IX. *The Skull and Dermal Armor of Stegosaurus;* by O. C. MARSH. (With Plates VI, VII, VIII, and IX.)

IN previous numbers of this Journal, the writer has given the more important characters of the skeleton of the *Stegosauria*, and has indicated the relations of this group to the other known *Dinosauria*.* The discovery of additional specimens of *Stegosaurus*, one of them nearly complete, furnishes material to greatly enlarge our knowledge of the skull and dermal covering of this genus, and some of the new facts are placed on record in the present article.

The results of the entire investigation of this group will be brought together in a monograph now in preparation, by the writer, for the U. S. Geological Survey. The lithographic plates for this volume, sixty-five in number, are nearly all printed, and the figures of the skull here given are taken from these plates.

* This Journal, vol. xiv, p. 513, Dec., 1877; vol. xix, p. 253, March, 1880; vol. xxi, p. 167, Feb., 1881; and vol. xxiii, p. 83, Jan., 1882.

The Skull.

The skull of *Stegosaurus* is long and slender, the facial portion being especially produced. Seen from the side, with the lower jaw in position, it is wedge-shaped, with the point formed by the premaxillary, which projects well beyond the mandible, as shown in figure 1, Plate VI. The anterior nares (*a*) are large, and situated far in front. The orbit (*b*) is very large, and placed well back. The lower temporal fossa (*c*) is somewhat smaller. All these openings are oval in outline, and are on a line nearly parallel with the top of the skull. In this view, the lower jaw covers the teeth entirely.

Seen from above, as shown in figure 3, Plate VI, the wedge-shaped form of the skull is still apparent. The only openings visible are the supra-temporal fossæ (*e*). The premaxillary bones (*pm*) are short above, but send back a long process below the narial orifice. The nasal bones (*n*) are very large, and elongate. They are separated in front by the premaxillaries, and behind, by anterior projections from the frontal bones. The prefrontals (*pf*) are large, and are placed between the nasals and the prominent, rugose supra-orbitals (*so*). The frontals are short, and externally join the postfrontals (*fp*). The parietals are small, and closely coössified with each other.

Viewed from in front, the skull and mandible present a nearly quadrate outline (Plate VI, figure 2), and the mutual relations of the facial bones are well shown. In this view is seen, also, the predentary bone (*pd*), a characteristic feature of the mandible in this genus. The lateral aspect of this bone in shown in figure 1.

The teeth in this genus are entirely confined to the maxillary and dentary bones, and are not visible in any of the figures here given. They are small, with compressed, fluted crowns, which are separated from the roots by a more or less distinct neck. The premaxillary and the predentary bones are edentulous.

The present skull belongs to the type specimen of a new and very distinct species, which may be called *Stegosaurus stenops*. The skull and nearly complete skeleton of this specimen, with nearly all the dermal armor in place, were found almost in the position in which the animal died.

This animal was much smaller than those representing the other species of this genus. Its remains were found by Mr. M. P. Felch, in the Atlantosaurus beds of the Upper Jurassic, in southern Colorado. In this geological horizon, all the known American forms of *Stegosauria* have been discovered.

The Dermal Armor.

The osseous dermal covering of the *Stegosauria* was first described by the writer, from specimens found associated with several skeletons, but not in place, and hence, the position of the various parts was a matter of considerable doubt. Subsequent discoveries have shown the general arrangement of the plates, spines, and ossicles, and it is now evident that, while all the group were apparently well protected by offensive and defensive armor, the various species, and perhaps the sexes, differed more or less in the form, size, and number, of portions of their dermal covering. This was especially true of the spines, which are quite characteristic in some members of the group, if not in all.

The skull was evidently covered above with a comparatively soft integument. The throat and neck below were well protected by small, rounded and flattened ossicles having a regular arrangement in the thick skin. One of these ossicles is shown in Plate VII, figure 1. The upper portion of the neck, back of the skull, was protected by plates, arranged in pairs on either side. These plates increased in size farther back, and thus the trunk was shielded from injury. From the pelvic region backward, a series of huge plates stood upright along the median line, gradually diminishing in size to about the middle of the tail. One of these is shown in Plate VII, figure 3. Some of the species, at least, had somewhat similar plates below the base of the tail, and one of these bones is represented in figure 2 of the same plate.

The offensive weapons of this group were a series of huge spines arranged in pairs along the top of the distal portion of the tail, which was elongate and flexible, thus giving effective service to the spines, as in the genus *Myliobatis*.

In *Stegosaurus ungulatus*, there were four pairs of these spines, diminishing in size backward. Two of the larger of these are shown on Plate VIII, figures 2 and 3. In some other forms, there were three pairs, and in *S. stenops*, but two pairs have been found.

In one large species, which may be called *Stegosaurus sulcatus*, there is at present evidence of only one pair of spines. These are the most massive of any yet found, and have two deep grooves on the inner face, which distinguish them at once from all others known. One of these grooved spines is represented on plate VIII, figures 4, 5, and 6.

The position of these caudal spines with reference to the tail is indicated in the specimen figured on Plate IX, which shows the vertebræ, spines, and plate as found.

The American genera of the *Stegosauria* are *Stegosaurus* and *Diracodon.* Of the former, there are several well-marked species besides *S. armatus,* the type. Of the latter genus, but one is known at present, *Diracodon laticeps,* the remains of which have hitherto been found at a single locality only, where several individuals referred to this species have been discovered. Aside from the form of the skull, these specimens have in the fore foot the intermedian and ulnar bones separate, while in *Stegosaurus,* these carpals are firmly coössified.

All the known American forms appear to have the second row of carpals unossified, and five digits in the manus. In the hind foot, the astragalus is always coössified with the tibia, even in very young specimens, while the calcaneum is sometimes free. The second row of tarsals is not ossified in any of the known specimens. Only four digits in the hind foot are known with certainty, and one of these is quite small. All forms have at least three well-developed metatarsals, which are short and massive, but longer and much larger than the metacarpals. Most of the bones originally referred to the hind foot of *Stegosaurus ungulatus,* and figured as such (this Journal, vol. xxi, Plate VIII), although found with the posterior extremities, subsequently proved to belong to the fore foot of another larger species.

In one large specimen, of which the posterior half of the skeleton was secured, no trace of dermal armor of any kind was found. If present during life, as indicated by the massive spines of the vertebræ, it is difficult to account for its absence when the remains were found, unless, indeed, the dermal covering had been removed after the death of the animal, and previous to the entombment of the skeleton where found. In this animal, the ilia were firmly coössified with the sacrum, thus forming a strong bony roof over the pelvic region, as in birds.

This specimen represents a distinct species, which may be called *Stegosaurus duplex.* It was originally referred by the writer to *S. ungulatus,* and the pelvic arch figured under that name.* In the sacrum of this species, each vertebra supports its own transverse process, or rib, as in the *Sauropoda,* while in *S. ungulatus,* the sacral ribs have shifted somewhat forward, so that they touch, also, the vertebra in front, thus showing an approach to some of the *Ornithopoda.*

* This Journal, vol. xxi, Plate VII, Feb., 1881.

The large number of specimens of the *Stegosauria* now known from the American Jurassic, and the fine preservation of some of the remains, enable us to form a more accurate estimate of the relations of the group to the other Dinosaurs, than has hitherto been possible. The presence of a predentary bone, and the well-developed post-pubis, are important characters that point to the *Ornithopoda* as near allies, with a common ancestry. These positive characters are supplemented by some points in the structure of the skull, and the form of the teeth.

There are, however, a large number of characters in which the *Stegosauria* differ from the *Ornithopoda*, and among these are the following:

(1) All the bones of the skeleton are solid.
(2) The vertebræ are all biconcave.
(3) All the known forms have a strong dermal armor.
(4) The second row of carpals and tarsals are unossified.
(5) The astragalus is coössified with the tibia.
(6) The spinal cord was greatly enlarged in the sacral region.

The relations of these two groups to each other and to the rest of the known *Dinosauria* will be fully discussed by the writer in his monograph on the *Stegosauria.*

New Haven, Conn., October 24, 1887.

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Chas. D. Walcott,
U. S. Geological Survey.

No. 204. Vol. XXXIV. DECEMBER, 1887.

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WITH PLATE X.

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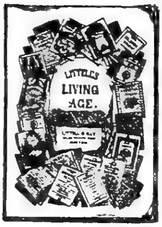

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XLVI.—*On the Destruction of the Passivity of Iron in Nitric Acid by Magnetization*;* by EDWARD L. NICHOLS and W. S. FRANKLIN.

I.

DURING the winter of 1884–85, the authors of this paper were engaged in the investigation of the chemical behavior of iron in the magnetic field. In the course of their experiments a beaker containing powdered iron, submerged in cold concentrated nitric acid, was placed between the poles of a small electro-magnet. While in the magnetic field the iron was touched with the bulb of a thermometer, used in the determination of the temperature of the acid, whereupon it lost its passivity and the solution burst into violent effervesence. The reaction continued until the beaker was removed from the field, when the iron again became passive. This change of condition was found to be due to the action of the magnet, occurring instantly in solutions of high temperature or of small degrees of concentration, and taking place upon stirring in the field, even in the case of iron in cold, concentrated acid. The further study of this phenomenon, of which brief mention has

* Paper read before the Kansas Academy of Science, November, 1885, with a supplementary note of later date.

been made in the published account of the above mentioned investigation,* forms the subject of the present paper.

The influence of the electric current upon the passivity of iron has been known for half a century, Schoenbein having described the phenomenon at some length in the well-known letter to Faraday, in which the discovery of the passive state was first announced.† Faraday followed up Schoenbein's work with a variety of ingenious experiments of his own, and reached the conclusion that the passive state is due to the formation of a film of insoluble oxide upon the metal, and that the power of the electric current to produce passivity in iron, which acts as a positive electrode, lies in the liberation of free oxygen upon its surface. This view of the matter has been confirmed by the researches of Boutmy and Chateau,‡ who pointed out the power of chromic, sulphuric and permanganic acids to promote passivity, and by the more recent investigations of Renard,§ in which it was shown that all reducing agents have a tendency to destroy the passivity of iron, whereas oxidizing agents tend to bring about the passive state.

II.

The behavior of iron in nitric acid solutions varies in the most striking manner with the temperature and strength of the acid and with the molecular condition of the metal.

The active metal may be dissolved with evolution of nitrous fumes and the production of a ferric salt, with the evolution of hydrogen and the production of a ferrous salt, or without the evolution of any gas.‖

In anticipation of similar variations in the transition from the passive to the active state, it was thought best, before entering upon the study of the influence of magnetization upon passivity, to make the following preliminary experiments:

(1). *On the behavior of passive iron in cold nitric acid.*—One gram of powdered iron was placed in 8^{cc} of nitric acid, sp. gr. 1·368, and allowed to stand. The metal was apparently entirely passive and remained so throughout the experiment. The temperature of the solution was 20° C. Upon standing, the acid began to show signs that the passivity was not complete; at the end of an hour the amount of iron in solution being sufficient to color the acid unmistakably. Repetitions of the experiment, always with the same result, led to the conclusion that in

* On the Chemical Behavior of Iron in the Magnetic Field, this Journal, April, 1886, vol. xxxi, p. 272.

† Faraday: Experimental Researches, vol. ii, pp. 237–244.

‡ Boutmy and Chateau: Cosmos, xix, p. 117.

§ Renard: Comptes Rendus, vol. lxxix, No. 5.

‖ Ordway: this Journal, II, vol. xl, p. 316.

the case of finely divided "iron by alcohol," in strong acid, Ordway's third reaction (the solution of the iron without the evolution of gas) was always going on.

(2). *On the destruction of passivity by heat.*—A test-tube containing passive iron in strong nitric acid was placed in a water-bath and heated. Rise of temperature was found to increase the rapidity of the reaction without evolution of gas. This was gradually supplanted by the second reaction described by Ordway (with the elimination of hydrogen), effervesence becoming very evident at 60°. Under these conditions the metal could not be regarded as "passive" in the strict sense of the word, and yet the reaction differed entirely from that of strong acid upon active iron. At this temperature the concentrated acid acted upon the passive iron in a way similar to that in which a very dilute acid attacks the active metal.

The transition between these two reactions was not sharply marked. Further heating increased the effervesence until, within the neighborhood of 80°, nitrous fumes began to be evolved. The reaction was still far from equaling that which such acid is capable of exerting upon active iron, but the condition of the solution became more and more unstable, and a slight further rise of temperature sufficed to render the iron subject to the full effect of the acid. This final and complete loss of passivity was very sharply marked by the setting in of a reaction of fairly explosive violence.

Repetitions of this experiment showed that the temperature, at which these successive changes occur, depends upon a variety of circumstances. It was found to vary with the time the iron had been exposed to the acid, with the strength of the latter, and with the character of the iron. Even the presence of small quantities of the salts produced by these reactions was found to influence in a marked degree the temperature at which, in a subsequent trial, the metal became active.

(3). *On the influence of time.*—The influence of the time of exposure upon the temperature of the loss of transition was first noticed during the experiment just described. A test-tube containing passive iron in nitric acid had been allowed to stand for some time before being placed in the water-bath. Instead of retaining its passivity to a temperature of nearly 90°, this specimen became active at a much lower temperature. Repeated trials showed that continued exposure always lowered the temperature at which passivity was lost. To determine the extent of this variation, other conditions were kept as nearly uniform as possible and the iron was exposed, for different intervals of time, to the acid before the destruction of its passivity. The control of conditions but imperfectly understood was far from complete, and the results of the determination

showed irregularities which would doubtless disappear—had the time been the only remaining source of variation. The series given in the following table is thought, however, to indicate, with a fair degree of accuracy, the influence of the time of exposure upon the temperature of loss of passivity. The time given is that which elapsed between the placing of the iron in the acid and its change to the active condition. It will be seen that the temperature of transition falls as the time of exposure increases.

TABLE I.

Influence of the duration of exposure to the acid upon the temperature at which iron becomes active in NHO_3, sp. gr. 1·368.

DURATION OF EXPOSURE.	TEMPERATURE OF TRANSITION.
$0^m\ 45^s$	89·4°
$1^m\ 2^s$	84·2°
$4^m\ 25^s$	79·3°
$6^m\ 25^s$	78·7°
$9^m\ 30^s$	78·3°
$13^m\ 50^s$	71·5°
$25^m\ 30^s$	70·8°

(4). *On the influence of the presence of iron salts in the solution.*—The presence of even a small amount of the final products of the action of nitric acid upon iron was found to lower the temperature of transition to the active state to a marked extent. In order to obtain consistent results it was necessary to clean the test-tubes in which the reaction was to take place, and the thermometer, by boiling in sulphuric acid. Failure to thoroughly cleanse the latter repeatedly reduced the temperature of transition many degrees, in one instance to 60°, and in a test-tube from which the products of a former reaction had not been entirely removed, it was often impossible to render iron passive even at 20°.

(5). *On the influence of the strength of acid.*—A more obvious cause of variation in the temperature of transition than those already described, lies in the different strengths of acid in which the iron is submerged. A set of experiments upon this variation gave the following results:

TABLE II.

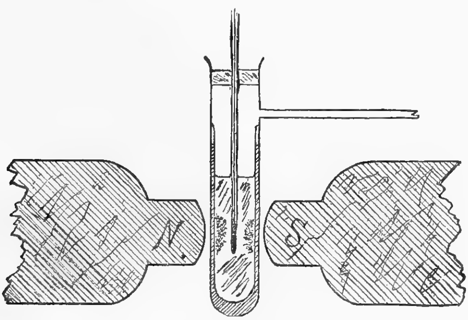
Temperature of transition from the passive to the active state in acid of different degrees of concentration.

SP. GR. OF ACID.	TEMPERATURE OF TRANSITION.
1·368	89·5°
1·354	82·3°
1·306	69·6°
1·130	23·0°

The time of exposure to the acid was in each case about 40 seconds. This determination agrees well with that noted by Schoenbein for iron wire in nitric acid, sp. gr. 1·35. He found the change to occur at 75°.

III.

In these preliminary experiments the method pursued had been very simple. The powdered iron was placed in a perfectly clean and dry test-tube, and the acid having been measured out was poured upon it. The test-tube was then placed in a water-bath, a thermometer was inserted in the acid, and the transition-temperature, always indicated by an explosion of such violence as to expel the greater portion of the contents of the tube, was noted. In order to protect the observer from the explosion, an inverted glass funnel was set over the whole, part of the thermometer projecting beyond the tube of the funnel. In carrying on similar experiments in the field of an electro-magnet, more complete protection from the acid fumes was obtained by means of the apparatus shown in the accompanying figure. The test-tube holding the iron and acid was



placed in a larger tube between the pole-pieces of the magnet. Into the mouth of the larger tube there was fitted a thermometer by means of a rubber cork. A long and narrow glass tube, sealed into the outer tube just below the cork, afforded an exit to the gaseous products of the reaction, which were caught over a pneumatic trough.

The electro-magnet was designed with special reference to this work. The diameter of the cores was 55^{mm}, and the pole pieces were so arranged that the tube containing the iron and acid could be brought in a nearly uniform field of high intensity. The magnet was actuated by a battery of "bichromate" cells, and the current-strength regulated by a rheostat of simple construction. The intensity of the magnetic field was esti-

mated by withdrawing a coil of small area from the field and comparing the consequent swing of a galvanometer needle with that produced in the same needle by a Weber's "earth-inductor."

With this apparatus the influence of magnetization upon the passivity of iron was studied under various circumstances. It was found very difficult, even with the knowledge of other causes of variation in the temperature of transition, gained by the preliminary experiments, to obtain entirely concordant results; but a number of interesting facts concerning the influence of the magnet were established. The following is a résumé of notes made during the investigation:

(*a*). 8^{cc} of HNO^3, sp. gr. 1·368, acting upon 1 gram of iron in the magnetic field. The tube containing the iron and acid was immersed in water, which up to the beginning of the experiment, had been boiling. The strength of the field, which was insufficient to destroy passivity at the temperature of the room (20°), was not measured.

Effervesence began at once and increased until the thermometer indicated 51°, when the explosion, characteristic of loss of passivity occurred, blowing most of the liquid from the tube. The remainder became quiescent again, but when touched with the thermometer-bulb its explosive activity returned. The reaction differed apparently in its nature from that taking place out of the field. The products of the reaction when poured from the tube, left the tube and thermometer-bulb clean, whereas, after the ordinary reaction they were thickly coated with a black residue, the removal of which necessitated long boiling in acid.

(*b*). A repetition of experiment (*a*), with the magnet not acting. The thermometer rose steadily to 89°, at which temperature the transition to the active state took place.

(*c*). Conditions those of experiment (*a*), magnet acting. Temperature of transition was 51°. It was noticed that passivity was not lost throughout the mass of powdered iron at once, but began at a single point on the side of the tube, whence streams of gas were evolved while the rest of the iron remained passive. From this, as a center, the action spread, until the entire mass became involved. The temperature noted was that at which activity had become general.

(*d*). Conditions those of the experiment (*a*), excepting that the magnet was inactive until the temperature of the solution reached 60°, when the circuit was closed. Passivity was destroyed at once by the action of the magnet.

(*e*). Conditions those of experiment (*a*), excepting that the circuit was made and broken at every degree from 40° upward. But little effect was produced until in the neighborhood of 60°, when each tap of the key was marked by mo-

mentary effervesence and by a sudden rise of the thermometer, which effects became more and more marked as the solution became hotter. Complete and permanent activity, such, namely, as was capable of maintaining itself without the continued action of the magnet, did not occur until a temperature of 87·5° had been reached.

(*f*). A repetition of experiment (*a*), but with a weaker field. The current-strength was 0·28 of that used in experiment (*a*). The magnet was active throughout the experiment. The temperature of transition to the active state was 84·5°.

(*g*). The acid and iron were placed in a bath at 20° and placed between the poles of the magnet. The current was much stronger than that employed in the experiment (*a*). The intensity of the field, determined by the method already described, was 20,000H. Loss of passivity in this field occurred instantly upon closing the circuit.

(*h*). The acid was diluted with one-half its bulk of water, and the iron, having been introduced under the protection of a strip of platinum, remained passive when the latter had been withdrawn. The temperature of the acid was 23°. The iron lost its passivity instantly in a field of small intensity, and regained it only when removed from the neighborhood of the magnet. The very slight residual magnetism of the electro-magnet was found to be sufficient to destroy passivity in this weak acid, the action recurring violently whenever the tube was brought between the poles of the magnet, even when the circuit was open.

Upon repeating this experiment with somewhat stronger acid the strength of field requisite to the destruction of passivity was found to be much greater. In three parts of acid and one of water the iron remained passive under the residual magnetism of the magnet, and even in the field produced by the current last employed. The tangent galvanometer, when transmission took place, indicated 0·16 of the current which had been necessary, in experiment (*a*), to destroy passivity in concentrated acid at 51°, and the field was approximately of half the strength of that under which in the strong acid (experiment *f*), iron had remained passive to 84·5°. In four parts of acid and one of water at a temperature of 23·3°, the iron remained passive until the current-strength reached ·23 of that used in experiment (*a*).

(*i*). To determine in what strength of acid iron would become active at ordinary temperatures in the earth's field, the usual quantity of iron was placed in 10^{cc} of concentrated acid, and the acid rapidly diluted with water, and with such small amounts of snow as were necessary to keep the mixture at 23°. Dilution was continued until the iron had become active.

The transition was much less clearly marked than at high temperatures or within the magnetic field, but repeated trials gave 13^{cc} as the amount of water to be added to destroy passivity.

(*j*). To 20^{cc} of concentrated nitric acid at 0°, containing passive iron, water was added, with snow in quantities sufficient to prevent any marked rise of temperature. The addition of $172 \cdot 3^{cc}$ of water and snow did not produce noticeable activity. When placed in the field of the electro-magnet (strength of field approximating 20,000H), effervescence began at once, and a dark green solution of higher density than the acid was formed with a brown magnetic precipitation. By a repetition of the experiment outside of the field, it was found that a trace of color could be detected when the acid was diluted to $\frac{1}{3}$, and that effervesence began when the strength of acid had been reduced to $\frac{1}{13}$. Further reduction to $\frac{1}{26}$ produced no other changes in the reaction, nor did it at any time approach in rapidity that taking place in like circumstances within the field.

It appears from these experiments that the action of the magnet is to lower the temperature of transition to the active state, and that the intensity of the magnetic field necessary to convert passive into active iron at a given temperature increases rapidly with the concentration of the acid. The establishment of a satisfactory theory of the influence of magnetization upon passivity will probably demand a more complete acquaintance with the phenomena touched upon in this paper, and a wider knowledge than we now possess of the subject of chemical action in the magnetic field.

University of Kansas, November, 1885.

Supplementary Note.

An investigation of the electric currents set up between iron electrodes within the magnetic field, completed by us since the presentation of this paper, seems to offer a very satisfactory explanation of the manner in which the chemical behavior of iron is modified, and its passivity destroyed in the magnetic field. We find that when two iron bars placed parallel to the lines of force in the field are submerged in any liquid capable of attacking iron, and when the ends only of one of the bars and the middle of the other bar are exposed to the liquid, the bar with ends exposed becomes in its voltaic relation to the other bar, as *zinc to platinum;* so that if the bars be connected by means of wires through a galvanometer, a permanent current will be found to flow in the circuit thus formed.

In the case of a single mass of iron exposed to an acid within the magnetic field, local currents will be set up between those parts of the metal in which magnetic poles are induced and the

intermediate neutral parts of iron, the poles becoming as *zinc* to the other portions, and the currents flowing from the poles through the liquid to the neutral parts of the metal. There is good reason to think that these local currents are the cause of the curious modifications in the chemical behavior of iron in the magnetic field, already described in the pages of this journal, and of the influence of magnetization upon the passivity of that metal. A full account of this research will be published at an early day.

June, 1887.

ART. XLVII.—*On a Method of making the Wave-length of Sodium Light the actual and practical standard of length;* by ALBERT A. MICHELSON and EDWARD W. MORLEY.

THE first actual attempt to make the wave-length of sodium light a standard of length was made by Peirce.* This method involves two distinct measurements: first, that of the angular displacement of the image of a slit by a diffraction grating, and second, that of the distance between the lines of the grating. Both of these are subject to errors due to changes of temperature and to instrumental errors. The results of this work have not as yet been published; but it is not probable that the degree of accuracy attained is much greater than one part in fifty or a hundred thousand. More recently, Mr. Bell of the Johns Hopkins University, using Rowland's gratings, has made a determination of the length of the wave of sodium light which is claimed to be accurate to one two hundred thousandth part.† If this claim is justified, it is probably very near the limit of accuracy of which the method admits. A short time before this, another method was proposed by Macé de Lepinay.‡ This consists in the calculation of the number of wave-lengths between two surfaces of a cube of quartz. Besides the spectroscopic observations of Talbot's fringes, the method involves the measurement of the index of refraction and of the density of quartz, and it is not surprising that the degree of accuracy attained was only one in fifty thousand.

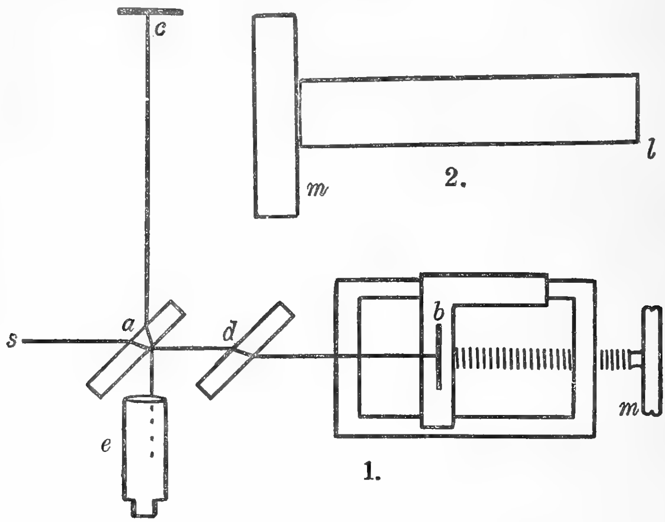
Several years ago, a method suggested itself which seemed likely to furnish results much more accurate than either of the foregoing, and some preliminary experiments made in June have confirmed the anticipation. The apparatus for observing the interference phenomena is the same as that used in the experiments on the relative motion of the earth and the luminiferous ether.

* Nature, xx, 99, 1879; this Journal, III, xviii, 51, 1879.

† On the absolute wave-lengths of light, this Journal, III, xxxiii, 167, 1887.

‡ Comptes Rendus, cii, 1153, 1886; Journ. de Phys., II, v, 411, 1886.

Light from the source at *s* (fig. 1), a sodium flame, falls on the plane parallel glass *a*, and is divided, part going to the plane mirror *c*, and part to the plane mirror *b*. These two pencils are returned along *cae* and *bae*, and the interference of the two is observed in the telescope at *e*. If the distances *ac* and *ab* are made equal, the plane *c* made parallel with that of the image of *b*, and the compensating glass *d* interposed, the interference is at once seen. If the adjustment be exact, the whole field will be dark, since one pencil experiences external reflection, and the other internal.



If now *b* be moved parallel with itself a measured distance by means of the micrometer screw, the number of alternations of light and darkness is exactly twice the number of wave-lengths in the measured distance; thus the determination consists absolutely of a measurement of a length and the counting of a number.

The degree of accuracy depends on the number of wave-lengths which it is possible to count. Fizeau was unable to observe interference when the difference of path amounted to 50,000 wave-lengths. It seemed probable that with a smaller density of sodium vapor this number might be increased, and the experiment was tried with metallic sodium in an exhausted tube provided with aluminum electrodes. It was found possible to increase this number to more than 200,000. Now it is very easy to estimate tenths or even twentieths of a wave-length, which implies that it is possible to find the number of wave-lengths in a given fixed distance between two planes with

an error less than one part in two millions and probably one in ten millions. But the distance corresponding to 400,000 wave-lengths is roughly a decimeter, and this cannot be determined or reproduced more accurately than say to one part in 500,000. So it would be necessary to increase this distance. This can be done by using the same instrument together with a comparer.

The intermediate standard decimeter *lm* (fig. 2) is put in place of the mirror *b*. It consists of a prism of glass one decimeter long with one end *l* plane, and the other slightly convex, so that when it touches the plane *m*, Newton's rings appear, and these serve to control any change in the distance *lm*, which has been previously determined in wave-lengths.

The end *l* is now adjusted so that colored fringes appear in white light. These can be measured to within one-twentieth of a wave-length, and probably to within one-fiftieth. The piece *lm* is then moved forward till the fringes again appear at *m*; then the refractometer is moved in the same direction till the fringes appear again at *l*, and so on till the whole meter has been stepped off. Supposing that in this operation, the error in the setting of the fringes is always in the same direction, the whole error in stepping off the meter would be one part in two millions. By repetition this could of course be reduced. A microscope rigidly attached to the carriage holding the piece *lm* would serve to compare, and a diamond attached to the same piece would be used to produce copies. All measurements would be made with the apparatus surrounded by melting ice, so that no temperature corrections would be required.

Probably there would be considerable difficulty in actually counting 400,000 wave-lengths, but this can be avoided by first counting the wave-lengths and fractions in a length of one millimeter and using this to step off a centimeter. This will give the nearest whole number of wave-lengths, and the fractions may be observed directly. The centimeter is then used in the same way to step off a decimeter, which again determines the nearest whole number, the fraction being observed directly as before.

The fractions are determined as follows: the fringes observed in the refractometer under the conditions above mentioned can readily be shown to be concentric circles. The center has the minimum intensity when the difference in the distances *ab ac* is an exact number of wave-lengths. The diameters of the consecutive circles vary as the square roots of the corresponding number of waves. Therefore, if x is the fraction of a wave-length to be determined, and y the diameter of the first dark ring, d being the diameter of the ring corresponding to one wave-length, then $x = \frac{y^2}{d^2}$.

There is a slight difficulty to be noted in consequence of the fact that there are two series of waves in sodium light. The result of this superposition of these is that as the difference of path increases, the interference becomes less distinct and finally disappears, reappears, and has a maximum of distinctness again, when the difference of path is an exact multiple of both wave-lengths. Thus there is an alternation of distinct interference fringes with uniform illumination. If the length to be measured, the centimeter for instance, is such that the interference does not fall exactly at the maximum—to one side by, say, one-tenth the distance between two maxima, there would be an error of one-twentieth of a wave-length requiring an arithmetical correction.

Among other substances tried in the preliminary experiments, were thallium, lithium, and hydrogen. All of these gave interference up to fifty to one hundred thousand wave-lengths, and could therefore all be used as checks on the determination with sodium. It may be noted, that in case of the red hydrogen line, the interference phenomena disappeared at about 15,000 wave-lengths, and again at about 45,000 wave-lengths: so that the red hydrogen line must be a double line with the components about one-sixtieth as distant as the sodium lines.

ART. XLVIII.—*The work of the International Congress of Geologists;* by G. K. GILBERT.

[Address delivered before the Section of Geology and Geography of the American Association for the Advancement of Science, at the New York meeting, August 10, 1887.]

ELEVEN years ago this Association met at Buffalo. It was the year of the Centennial Exhibition, and we were honored by the presence of a number of European geologists. This naturally opened the subject of the international relations of geology, and the proposition to institute a congress of geologists of the world took form in the appointment by the association of an International Committee. The project thus initiated found favor elsewhere, and there resulted an international organization, which up to the present time has held three meetings. It convened first at Paris in 1878, then at Bologna in 1881, and at Berlin in 1885.* Its next meeting will be held in London next year, and an endeavor will be made to secure for the United

* The report of the Paris meeting, entitled *Congrès international de Géologie* is a document of the *Exposition universelle internationale de* 1878, *à Paris*, and covers 313 pages, 8°. The report of the Bologna meeting was printed by the Congress: "*Congrès géologique international, compte rendu de la 2me session, Bologna,* 1881;" pp. xv + 663, 8°. The official report of the Berlin meeting has not yet appeared; but its proceedings are abstracted in "The work of the International Congress of Geologists, and of its Committees. Published by the American

States the honor of the fifth meeting. The original committee of the association has been continued, with some change of membership, and has sent representatives to each session of the congress.

The work of the congress, as originally conceived and as subsequently undertaken, has for its scope geologic nomenclature and classification, and the conventions of geologic maps. The particular classifications attempted are the establishment of the major divisions used in historic and stratigraphic geology and the subdivision of volcanic rocks. In nomenclature three things are undertaken: first, the determination of the names of historic and stratigraphic divisions; second, the formulation of rules for nomenclature in paleontology and mineralogy; and third, the establishment and definition of the taxonomic terms of chronology (period, epoch, etc.), and of stratigraphy (system, series, etc.) The map conventions most discussed are colors, but all signs for the graphic indication of geologic data are considered. The congress has also undertaken the preparation of a large map of Europe, to be printed in forty-nine sheets.

The work was for the most part planned at the Paris meeting, and committees were appointed to formulate subjects for action by the congress at subsequent sessions. Briefly stated, the work accomplished to the present time is as follows: Agreement has been reached as to the rank and equivalence of the taxonomic terms employed in chronology and stratigraphy, a set of rules for paleontologic nomenclature has been adopted, and many sheets of the map of Europe have been prepared for the engraver. A partial classification of stratified rocks has been agreed to and also a partial scheme of map colors, but the reports of proceedings indicate that action in these matters is tentative rather than final.

It is understood that both of these subjects will have prominent place in the proceedings at the London meeting, and the American committee is endeavoring to prepare itself for representative action at that meeting by ascertaining the opinions of all American geologists on the various subjects. It has asked this Section to set apart a day for the discussion of some of the more important questions, and it can hardly be doubted that the Section will realize the mutual advantage of thus assigning the time requested.* I am personally so impressed with the im-

Committee, under the direction of Persifor Frazer, *Docteur des sciences naturelles* (*Univ. de. France*), Secretary. 1886;" pp. 109, 8°; and its work is summarized in "*Resultats scientifiques du Congrès géologique international de Berlin et des travaux qui s'y rattachent, par E. Renevier, prof.;*" pp. 22, 8°, in *Bull. Soc. Vaudoise Sci. Nat.*, vol. xxii, No. 94.

* A day was assigned, as requested. The Section listened to a report by the secretary of the committee, Dr. Frazer, and began to discuss it point by point, but adjourned without great progress. A resolution was passed approving the work of the Committee.

portance of the possible work of the congress that I shall devote the present hour also to its consideration.

The first thing the congress did was to select names for a set of categories to express the taxonomic rank of stratigraphic divisions, on the one hand, and of chronologic divisions on the other. In the terminology of zoology and botany the words kingdom, class, order, family, genus, species, etc., however difficult of definition they may severally be, nevertheless are used always in the same order of inclusion. No systematist in those sciences would think of grouping orders together and calling them a family, or of styling a group of families a genus. But in geology there is no such uniformity of usage. With some writers a group is larger than a series, with others it is smaller. With some an age includes several periods, with others a period includes several ages. There are even writers who ignore the distinction between stratigraphy and chronology; and among the classifications submitted to the congress is one in which an age is subdivided into systems. There is a manifest advantage in bringing order out of this chaos, and so great is the utility of uniformity and perspicuity that the decisions of the congress in this regard will unquestionably be followed by future authors. The terms and the order adopted by the congress are as follows: Of stratigraphic divisions that with the highest rank is *group*, then *system*, *series* and *stage*. The corresponding chronologic divisions are *era*, *period*, *epoch* and *age*. This order of rank is strange to most English readers and writers, and so is one of the terms—*stage*—but the strangeness is only a temporary disadvantage and will not seriously retard the adoption of the convention. The fact that we have previously used the words in a different sense, or that their etymology might warrant a different meaning, need not deter us, for we know from frequent experience that the connotations of a word transferred from one use to another quickly disappear from consciousness, leaving it purely denotative. The introduction of the word *stage*, which can hardly be said to have had an English status heretofore, or at least the introduction of some new word for that part of the column, was necessitated by the restriction of the word *formation* to a special meaning,—the designation of mineral masses with reference to their origin.

The same restriction vacated another office that had been filled by formation, and to this office no appointment was made. I refer to the use of the word to denote indefinitely an aggregate of strata—as in saying, This formation should be called a series rather than a system. This is an important function, for which some provision must be made. I suggest that we may advantageously enrich our language by the permanent adop-

tion of *terrane*, a word whose English meaning has not been well established.*

The fixation of the chronologic terms creates a similar difficulty. We have crystallized out of our magma the terms *era*, *period*, *epoch* and *age*, and there remain in the ground-mass only *eon*, *cycle* and *time*. Of these, *eon* has a poetic connotation which seems to unfit it for this particular use; *cycle* implies repetition or recurrence; and *time* has been so generally applied to unlimited duration that it is difficult to apply it also to limited duration, even though the nature of the limitation be indefinite. On the whole, *time* seems open to the least objection, but I cannot help regretting that either *period* or *age*, both of which have heretofore passed current in the indefinite sense, was not reserved by the congress for that function. With English-speaking peoples the word *eon* could have been better spared for the definite series.

But while the terms selected by the congress are not beyond criticism, the benefits to be derived from an agreement in an orderly system are so great that I for one shall unhesitatingly adopt them as they stand,—provided, of course, that the congress makes no effort to improve its selection.† A small reform of this nature yields its profit to this as well as future generations, and I hold it a duty to favor even those reforms which involve so much effort and pains that their blessings cannot be realized by those who initiate them. Such are the exchange of our English spelling for a rational system, and the exchange of decimal notation in arithmetic for a binary notation. My application of the new nomenclature begins with this address, in the preparation of which I have experienced its utility. That you may have no difficulty in interpreting my reformed language, I have placed the taxonomic legend on the wall, with the addition of the complementary indefinite terms, terrane and time.

Terranes.	Group.	Era.	Times.
	System.	Period.	
	Series.	Epoch.	
	Stage.	Age.	

There are propositions before the congress to distinguish the names of individual groups, systems, series and stages by means

* In a review of this paper, by Dr. Persifor Frazer, it is pointed out that this suggestion is not original with me, having been made by Prof. Renevier, at the Berlin meeting of the Congress, and that *terrane* is used in this sense in the pamphlet published by the American committee. The review, which consists chiefly of unfavorable criticism, may be found in the *American Naturalist* for September—vol. xxi, pp. 841–847.

† Several national committees favor the interchange of the words *group* and *series*.

of terminations, those of the same rank having the same termination. Thus it is proposed by a committee that every name of a group shall end in *ary*,—Tertiary, Primary, Archeary; it is proposed that names of systems end in *ic*,—Cretacic, Carbonic, Siluric; it is proposed that names of series end in *ian*,—Eifelian, Laramian, Trentonian; and it is proposed that stage names terminate with *in*. Another committee suggests that *ic* be used for stages instead of systems. The adoption of such a plan would enable a writer or speaker to indicate the taxonomic rank of a terrane without adding a word for that purpose. If he regarded a certain terrane taking its name from Cambria as a system, he would call it the Cambric; if he esteemed it only a series, he would say Cambrian; and there would be no need of adding the word system, or series, in order to express his full meaning. Conversely the reader or hearer would always learn its taxonomic rank, or supposed rank, whenever a terrane was mentioned. These I conceive to be the advantages derivable from the change, but they would not be the only effects. It would become impossible for a geologist to name or allude to a terrane without declaring its rank, and the consequences of this would be evil in many ways. In the first place one could not discuss terranes from any point of view without expressing an opinion as to their taxonomy, and the change would thus contravene one of the most important rights of opinion—namely, the right to reserve opinion. Again, geologists who differed as to the rank of a terrane would necessarily terminate its title differently, and a needless synonymy would thus be introduced. In the third place the created necessity for taxonomic discrimination on all occasions would tend to direct undue attention to taxonomic problems. Taxonomy would be conceived by many geologists as an end instead of a means, just as correlation has been conceived, and energy would be wasted in taxonomic refinement and taxonomic controversy. It is convenient for purposes of description and comparison to classify the strata that constitute a local columnar section in phalanges of various magnitude or rank, but the criteria on which we depend for discrimination are in the nature of things variable and offer ground for endless difference of opinion; and it would be extremely unfortunate to have such differences perpetually brought to the foreground.

Another subject considered by the congress is the nomenclature of paleontology. A committee appointed for the purpose formulated rules for the establishment of the names of genera and species, and their report was adopted by the congress. I have no opinion to express as to the wisdom of the rules, but it is a matter of surprise that a body of geologists assumed to speak with authority on the subject. From one point of view

paleontology is a part of geology; from another point of view it is a part of biology. In so far as it names genera and species it is purely biologic, and it would seem proper that the students of fossils unite with the students of living animals and living plants in the adoption of rules of nomenclature.

A similar remark applies to the nomenclature of mineralogy, in regard to which no action has yet been taken. The most intimate relations of systematic mineralogy are with chemistry.

Yet another projected work of the congress is the classification of eruptive rocks. Up to the present time action has been deferred, and it may reasonably be hoped that no scheme of classification will be adopted. If there existed a system of classification which gave general satisfaction and had stood the test of time, there would be little harm—and little or no advantage—in giving it the official stamp of approval. If the main features of a classification were well established and the residuary discrepancies were recognized as unessential, it is conceivable that some benefit might be derived from the submission of the matter to an assembly of specialists. But the actual case is far different. Not only is there wide difference as to the classification of volcanic rocks, but there is no agreement as to the fundamental principles on which their classification should be based, for we still lack an accepted theory of volcanism. At the same time observation is being pushed with great vigor, and with the aid of new and important methods. With the rapid growth of knowledge and ideas classifications are continually remodelled, and the best is in danger of becoming obsolete before it has been printed and circulated. Should the congress enter the lists, one of two things would occur. Either its classification would be treated like that of an individual and ignored as soon as a better one was proposed, or it would be regarded as more authoritative, and new facts would for a time be warped into adjustment with it. In either case the reputation of the congress would eventually suffer, and in one case science would suffer also.

There remain to consider the two most important undertakings of the congress, the classification of terranes and the unification of map colors. The congress is attacking these subjects indirectly by means of a third undertaking, the preparation of a geologic map of Europe, and this method of approach has had the effect of making it difficult properly to interpret its action. There can be no doubt that those who originally organized the work contemplated the enactment of a stratigraphic classification to be applied to the entire earth and the selection of a color scheme for use either in all geologic maps or in all general geologic maps. But at the Berlin session the committee in charge

of work on the map of Europe pressed the congress for the determination of questions on which hung the completion of the map, and many hasty decisions were reached, while not a few disputed points were referred to the map committee. The debates indicate that much or all of this work was provisional or of merely local application, but the resolutions adopted show little qualification. It should be added that the official minutes of the meeting are still unpublished. In view of the uncertainty thus occasioned I shall not attempt to characterize the attitude of the congress on the subject of classification, but shall merely develop my individual view.

It is the opinion of many who have discussed the general classification of terranes by convention of geologists that the smallest unit of such classification should be the stratigraphic system. What is a stratigraphic system? The congress implies a definition in saying that a system includes more than a series and less than a group, and that the Jurassic is a system; but this gives only a meagre conception and we need a full one. As the problem of classification demands a true conception of a system, and as there is reason to believe that a false conception is abroad, it is proper that in seeking the true one we begin with the elements.

The surface of the land is constantly degraded by erosion, and the material removed is spread on the floor of the ocean, forming a deposit. This process has gone on from the dawn of geologic history, but the positions and boundaries of land and ocean have not remained the same. Crust movements have caused the submergence of land, and the emergence of ocean bottom, and these movements have been local and irregular, districts here and there going up while other districts went down. The emergence of ocean bottom exposes the deposit previously made on it and subjects it to erosion. In this way every part of the known surface of the globe has been the scene of successive deposition and erosion, and in many districts the alternations of process have been numerous. It is manifestly impossible that either erosion or deposition should have ever prevailed universally, and it has been established by the study of stratigraphic breaks that a time of erosion has often interrupted deposition in one region while deposition was uninterrupted in another.

In transportation from its region of erosion to its place of deposition detritus is assorted, and it results that the simultaneous deposits on the bottom of an ocean are not everywhere the same. Equal diversity is shown in the ancient deposits constituting geologic formations. It is a general fact that synchronous formations have not everywhere the same constitution.

Many of the variations in deposits are correlated with depth

of water and distance from shore, and it results that elevation and subsidence in regions of continuous deposition produce changes in the nature of the local deposit.

The animals and plants of the earth are not universally distributed, but are grouped in provinces. In the geologic past similar provinces existed, but their boundaries were different, shifting in harmony with the varying geography of the surface. From time to time the barriers separating contiguous provinces have been abolished, suffering them to coalesce; and conversely new barriers have arisen, creating new provinces. From the earliest paleozoic to the present time the species of animals and plants have been progressively modified, the nature of the modification depending on local conditions. The faunas and floras of different provinces thus become different, and the longer the provinces remain distinct, the greater is the divergence of life. The removal of a barrier either produces a new fauna by the fusion of the two previously separated, or else obliterates one and extends the area of the other. In either case there is a change toward the unification of life, and in either case there is an abrupt change in a local fauna. Thus the secular evolution of species, combined with the secular and kaleidoscopic revolution of land areas, leads to two antagonistic tendencies, one toward diversity of life on different parts of the globe, the other toward its uniformity. The tendency toward uniformity affords the basis for the correlation of terranes by comparison of fossils; the tendency toward diversity limits the possibilities of correlation.

If now we direct attention to some limited area and study its geology, we find that under the operation of these general processes it has acquired a stratigraphic constitution of a complex nature. Its successive terranes are varied in texture. Breaks in the continuity of deposition are marked by unconformities. The fossils at different horizons are different, and when they are examined in order from the lowest to the highest, the rate of change is found to vary, being in places nearly imperceptible and elsewhere abrupt. It is by means of such features as these—that is, by lithologic changes, by unconformities, and by life changes—that the stratigraphic column is classified into groups, systems, series and stages. A system is a great terrane separated from terranes above and below by great unconformities, or great life breaks, or both. Smaller unconformities, smaller life changes, and lithologic changes are used for the demarcation of series and stages; and on the other hand, exceptionally great unconformities and life breaks are used to delimit groups. As the same criteria determine groups, systems and series, differing only in degree, the precise definition of the term system is impossible, and in many cases the gradation of a terrane as a group, a system or a series is largely a matter of convenience.

From this point of view a system is somewhat artificial, but there is a more important sense in which it is natural. It is limited by stratigraphic or paleontologic breaks above and below, and these breaks are natural. The taxonomist is not warranted in dividing systems where no such break exists.

Transferring now our attention to some other area, distant from the first, and studying its stratigraphy, we find that the same principles enable us to divide it independently into stages, series, systems and groups. Its fossils are not the same, but they are to a certain extent similar, and the sequence of life is approximately parallel. We cannot compare stage with stage, nor series with series perhaps, but we can compare system with system, and making the comparison we discover that the breaks are at different places. While one area was upraised and subjected for a time to erosion, the other received continuous deposition. While life in one area, enjoying constant conditions, was almost unchanged for long ages and even epochs, it was revolutionized in the other by the irruption across some obsolescent barrier of strong and aggressive faunas and floras. The systems of one area, therefore, do not coincide with the systems of the other in their beginning and ending. They may differ in number, and they may differ greatly in magnitude and in the duration they represent. They are in fact a different set of systems.

The case I have described is ideal but not false. It represents the common experience of those who have developed the geologic histories of remote districts and attempted to correlate them with the geologic history of Europe. There does not exist a world-wide system nor a world-wide group, but every system and every group is local. The classification developed in one place is perfectly applicable only there. At a short distance away some of its beds disappear and others are introduced; farther on its stages cannot be recognized; then its series fail and finally its systems and its groups.

If I have properly characterized stratigraphic systems—if they are both natural and local—it goes without saying that the classification of the strata of all countries in a dozen or so systems, as proposed by some of the members of the congress, is impossible.

I hasten to add that from the point of view of these gentlemen what they advocate is not necessarily impossible, for they have a different conception of a system. They regard it not as local but as universal. It is their privilege to define their terms as they please, and we will not dispute about mere words, but I cannot too strongly or too earnestly insist that a system which is universal is artificial. It may be natural in one geologic province, but it is artificial in all others. Take for example the

Jurassic. It is a natural system in Europe. In the eastern United States no strata are called Jurassic with confidence, and at the west the rocks called Jurassic merge with those called Triassic. In India, Medlicott tells us, a Jurassic fauna occurs at the summit of a great natural system containing a Permian fauna near its base.* In New Zealand, according to Hutton, a continuous rock system, dissevered by great unconformities from other systems, bears at top fossils resembling those of the lower Jurassic and lower down fossils of Triassic facies.† To establish a Jurassic system in either of these countries it is necessary to divide a natural system, and a Jurassic system thus established would be necessarily artificial.

This is the sort of classification implied by the assumption that systems are world-wide. It is not impossible, but it is highly unadvisable. It is classification for the sake of uniformity, and its uniformity is procrustean. The natural systems of a region are the logical chapters of its geologic history. If you group its strata artificially according to the natural divisions of another region, you mask and falsify its history. The geologic history of the earth has as great local diversity as its human history. As in human history there are interrelations and harmonies and a universal progress, but these are perceptible only in the general view; and the student whose preconceptions lead him to exaggerate the harmonies and ignore the discrepancies perverts the meaning of every page.

I prefer therefore my own definition of system, making it natural and consequently local, and I earnestly oppose any attempt to coerce the geology of one country in a rigid matrix formed over and shaped by the geology of another country.

The ideas I oppose have arisen in connection with the work of correlation. Some geologists appear to regard correlation as the determination in distant localities of identities; the more philosophic regard it as the determination of the actual relations, whether they be of identity or difference. With the former the basis of correlation is the universality of geologic systems; with the latter it may be said to be the universality of geologic time.

Now in the comparative study of local geologic histories, just as in the comparative study of local human histories, it is a matter of convenience to have a common scale of time. It is not essential, but it is highly convenient. In human history we use an astronomic scale of equal parts, designating each unit by a number. In geology no scale of equal parts is available, and we employ the eras and periods, and to some extent

* *Sur le coloriage des Cartes geologiques, par M. H. B. Medlicott;* in *Congrès géologique international, Compte rendu de la 2me session, Bologne,* 1881, pp. 652–656.

† Sketch of the Geology of New Zealand. By Captain F. W. Hutton. In Quart. Jour. Geol. Soc. London, vol. xli, pp. 191–220.

the epochs, of the local geologic history first deciphered—that of Europe. These time divisions bear the same names as the groups, systems and series of strata whose deposition occurred within them.

So far as the science of geology is concerned the selection of Europe as its first field of study was a matter of chance, and the adoption of the European time scale as a general standard may therefore be said to have been accidental. Though the local rock scheme on which it is based is natural, the time scale, considered as universal, is arbitrary. Another locality would have afforded a different scale, but its authority would neither be greater or less. The scale being recognized as arbitrary, and a mere matter of convenience, it is legitimate to modify and fix it by formal convention. The Congress can do good service to geologic technology by putting it in the best possible shape and giving it an official status. In my judgment only a small number of divisions should be admitted, not more than the number of periods of the European scheme. In a general way the durations represented by the coördinate divisions should be as nearly equal as practicable, but a certain concession might be made to chronologic perspective on account of our superior opportunities for studying the later history. Some of the shorter periods might perhaps be united under new names. Each line of division between periods should be defined by means of a stratigraphic plane of division, and this can be done with precision if a locality is made part of the definition.

Especially should pains be taken to declare the arbitrary nature of the scale. Even with this precaution it will be misconstrued by many, for there is a tendency of the mind to attach undue weight to classification. Wherever we draw lines of separation we lose to a certain extent the power to recognize continuity. When, for example, the clock strikes twelve on New Year's Eve time seems to stop and begin again. We speak of the achievements of the nineteenth century—and despite ourselves we think of them, too—as though a new industrial epoch began in A. D. 1800. And so it is easy for the beginner in geology to accept as discontinuous the eras and periods of which his text-book treats, and it is hard for him afterward to unlearn the lesson.

There is reason to believe that confusion of ideas in regard to geologic classification has been fostered by the employment of the same set of names for the divisions of the time scale and for the local terranes on which they are founded. It might be well to furnish the time scale with names suggesting time—such names as the brothers Rogers applied to the terranes of Pennsylvania—but so radical a change is hardly feasible, especially

as we should thus lose the mnemonic connection of times with corresponding terranes. I propose as a means of accomplishing the end with the least inconvenience, that a set of time words be derived from the terrane names by modifying the final syllables. The time words should all have the same termination, and that should differ from any terminations occurring in the terrane names. I suggest for the ending of time words the syllable *al*. With such a nomenclature Jurassic and Devonian would denote only certain European rock systems, while Jural and Devonal would denote periods of the standard time scale; and we could speak of the Chico-Tejon series as partly Eocenal and partly Cretaceal without seeming to imply the existence in California of the Eocene and Cretaceous systems of Europe.

A few minutes ago I opposed the differentiation of words by terminations because it abrogated the power of indefinite expression; I now favor it for the same reason. It is well to be indefinite as to the taxonomic rank of terranes while their characters are imperfectly known, but it is not well to confuse terranes with times.

It is not to be assumed that a time scale adopted now as the best possible will continue indefinitely to be the best possible; the day will inevitably come when it can be improved. In the fuller light of the future we may recognize as very unequal periods that we now deem equivalent, and the possibilities of defining pre-Cambrial periods are unlimited. Even now there are announced beneath the lowest fossil-bearing terranes of the Lake Superior region two systems of clastic rocks limited above and below by great unconformities, and Irving demands their recognition as a group, distinct from the Archæan. If his voice is heard, the time scale will include an era between the Paleozoal and the Archeal, and this era will supply the needs of the systematist until great additions have been made to our present knowledge of the older rocks.

My only remaining subject is the representation of terranes on maps by means of colors. At present no two organizations and scarcely two individuals use colors in the same way, and it is probably true that every organization and individual publishing many geologic maps has at different times employed the same color for different terranes and different colors for the same terrane. It results that the map user can gain no information from the distribution of colors until he has studied the legend; before he can read a new atlas he must learn a new alphabet. The advantage to be gained by substituting a universal language for this confusion of tongues is manifest and great, and has justified the application of much time and attention by the Congress and its committees. By a series of

resolutions a partial scheme has been selected, one color at a time, and the completion of the plan has been left to the committe on the map of Europe. That committee has prepared a color legend, which is accessible to American geologists in the volume of information published by the American committee. It is understood in a general way that the Congress reserves final action, and the published legend not only belongs specifically to the map of Europe, but is provisional; still, as this map, if generally approved, will unquestionably be declared by the Congress an authoritive pattern for the guidance of map makers, the plan should be freely criticised at its present stage. The selection of uniform colors is a far more delicate and important matter than the arrangement of taxonomic terms; for while ill-chosen words may quickly fit themselves to new uses, the adoption of an ill-arranged color scheme must entail continual loss.

In my judgment the scheme provisionally chosen is defective in several particulars, to which I shall presently call attention, but it is neccessary to introduce the discussion by a statement of the conditions to be satisfied by a standard color scheme and a statement of the practical means available. The following are the principal conditions, arranged in an order embodying my estimate of their relative importance:

(1). The map must be clearly and easily legible. Each color must be so distinct from each other color that it can be identified, whatever its surroundings; and all other conventions must be readily discriminated.

(2). The cartographic scheme must be adjustable to the geologic facts; it must not require that the facts be adjusted to it.

(3). The same scheme should serve both for general maps, as, for example, those representing only systems, and for detail maps, representing numerous smaller divisions.

(4.) Undue expense should be avoided. The amount and consequent utility of color cartography is largely limited by its cost.

(5). It should be easily fixed and retained in the mind. This is best accomplished by making it orderly.

(6). Other considerations permitting, the map should please the eye. Since the arrangement of color areas cannot be foretold, this can only be accomplished by admitting a certain range of choice. If allowed sufficient latitude in the selection of tones, an expert colorist can ameliorate an offensive combination of hues.

(7). Other considerations permitting, the establishment of a universal system should involve the least possible inconvenience. But as the inconvenience of change is temporary, while the inconvenience of a bad system is lasting, this consideration should yield to every other.

The art of mapping geologic terranes by means of color is well developed, and its methods, viewed from the geologist's standpoint, admit of easy characterization. Color may be varied in two distinct ways—in hue and in tone. Hues differ in quality, as yellowish green and bluish green. Tones differ in strength, as pale green and dark green. A color is printed either solid or broken; it is said to be broken when applied in a pattern, as in lines or dots, or when it is interrupted by a pattern. The difference between solid and broken colors is a difference of texture. The primary discriminations in mapping are through hue, tone and texture.

The map engraver produces texture in three ways. In the first way a single impression is made with a broken color. The white of the paper, displayed where the color is interrupted, combines with the color in the general effect, producing a paler tone of the same hue. In the second way two impressions are made, one with solid color the other with broken, and the two impressions have the same hue; they may or may not differ in tone. This is monochromatic overprinting, and its general effect agrees in hue with the single impression, but differs in tone, being darker. In the third way two impressions are made, one solid, one broken, and their colors differ in hue. This is bichromatic overprinting, and its general effect differs in hue as well as tone from each of the colors combined in it. The first and second ways produce texture monochromatically and do not yield a new hue; the third way produces texture bichromatically and yields a new hue. It is practically impossible to obtain a texture effect without modifying the original tone.

The natural gradation from hue to hue is absolutely continuous and the number of hues is infinite; the number of tones of each hue is likewise infinite. The number of hues and tones the eye can discriminate is finite, but very great; it is stated that one thousand hues have been distinguished in the solar spectrum. But the number of hues and tones that can be combined in a map is small. As a matter of perception, every color is modified by the colors adjacent to it. The same hue affords different sensations when differently surrounded, and different hues may afford the same sensation. The same is true of tones; and there is a certain interdependence of hues and tones in this respect. In a geologic map each color is liable to fall into various combinations, and two colors little differentiated occasion confusion. There is, therefore, a somewhat narrow limit to the employment of hues and tones. The matter has not been fully worked out, but it is probable that twenty is as large a number of hues as can be safely employed in connection with tones. Texture admits of very great variation. The various color schemes submitted to the congress and

printed in the report of the Bologna meeting afford, with their manifest permutations, about two hundred distinct textures, and I am satisfied from a study of these and others that as many as one hundred can be chosen that are not subject to confusion. It follows that a map or atlas expressing few distinctions need use only hues, or only hues and tones, but where numerous distinctions are to be made, recourse must be had to textures.

The printing of a large number of textures of the same hue produces a greater number of tones than can be discriminated, and its effect is to confuse and nullify any distinctions (within the range of that hue) based purely on tone. The printing of a large number of bichromatic textures causes the same result, and it also produces a greater number of hues than can be discriminated; its effect is to confuse and nullify distinctions based purely on tone, or on hue, or on tone and hue together.

In the color scheme prepared for the map of Europe thirty-eight distinctions are made. There are twenty-four hues, and the remaining fourteen distinctions are accomplished by variations of tone. While it may be possible to select twenty-four hues availiable for indiscriminate combination, there can be no question that those provisionally printed by the committee will fail to maintain their distinctness when variously combined upon a map. Under the influence of such chromatic environments as are sure to be encountered, the four yellow hues of the Tertiary cannot be discriminated, and the same difficulty will arise with the two hues of gray assigned to the Carboniferous, and with the hues of gray and brown assigned respectively to the Permian and the Devonian. Some of the tones likewise are not sufficiently distinguished. Two of the blues of the Jurassic, two of the browns of the Devonian, two of the rose tones of the Archæan, and the two violets of the Trias are open to this criticism. A certain amount of adjustment can be made in the final selection of inks, and probably all the defects from tone can be thus remedied, but the confusion of hues is more difficult to eliminate, for the great number of the hues interferes with the separation of those that are too approximate. To strengthen one contrast is to weaken another.

In order to judge of the availability of the scheme for the production of detail maps, it is necessary to consider the resolutions of the congress as well as the printed legend. A resolution provides that the subdivisions of a system shall be represented by shades of the color adopted for the system, or by broken color or other texture devices, and it is further provided that the shades, whether produced by solid color or by texture, shall be so arranged that the darkest or strongest represent the lower divisions of the system.* The resolution is in

* *Congrès géologique international, Compte rendu de la 2me Session, Bologne,* 1881, p. 157.

French, and the word I have translated shade (*nuance*) is one which applies popularly to either hue or tone, while in the scientific terminology of chromatics it applies to hue only. The committee on the map has taken it in its popular sense, and has represented some subdivisions by hues, and others by tones; for example, Pliocene and Miocene are assigned two tones of the same hue, while Oligocene and Eocene have each a separate hue. The upper Cretaceous and part of the lower Cretaceous are assigned a green hue in two tones, while the Gault and the Wealden, classed as subdivisions of the lower Cretaceous, have independent hues of green. Of the six reds assigned to volcanic rocks, two agree in hue and differ in tone, while the remainder have distinct hues. As the legend stands, both major and minor distinctions, that is to say, the discrimination of groups, the discrimination of systems, and the discrimination of divisions smaller than systems, are all accomplished by differences of hue, while the discrimination of minor divisions is accomplished indifferently by variation of hue and by variation of tone. The same means performs several functions, and the same function is performed by several means.

It is stating the same thing from another point of view to say that the Congress and its committees have used the term color in its popular rather than its scientific sense. Scientifically, a color is a particular tone of a particular hue, and the number of colors is infinite. Popularly, a color is an assemblage of contiguous hues and their tones, to which a name has been given. Each hue and tone within the range covered by the name is a shade of the color. It is in this popular sense that the resolutions assign a color to each system, and assign shades of the system-color to the subdivisions of the system.

Now if in the variation of a system-color, by textures or otherwise, a single hue is adhered to, the system-color remains distinct from other system-colors throughout all its modifications and their modifications, but if hues as well as tones are varied, the inevitable result is confusion, for some of the hues of one system-color will approach too near to hues of other system-colors. With a multiplicity of minor distinctions the main distinction of system from system will be lost.

Another difficulty lies in the fact that the Quaternary and Devonian colors, while strongly contrasted in tone, are nearly identical in hue. This does not affect their use in a general map, but in a detail map the stronger tones of the Quaternary gray will approach too closely the paler tones of the Devonian brown.

These criticisms apply to those features of the scheme which affect its adoption for general and detail maps of European countries. There is one of equal or greater importance affect-

ing its application in other continents. It is adjusted to the rock systems of Europe exclusively, and makes no provision whatever for the systems of other parts of the earth. The geologists of Wisconsin, for example, cannot use it without calling the Keweenawan either Cambrian or Archæan. If they were in doubt which division should hold it, but inclined a little one way or the other, they could express their qualified opinion in the notation provided by the map committee; but having attained an unqualified opinion that the terrane belongs to neither of these two categories, they find no means for expressing their conclusions. The scheme cannot be applied to the geology of India, of New Zealand, or of Australia, without misrepresentation. It is not universal but local, and this because it is founded on the fallacy of a world-wide unity of geologic systems.

So far as the geology of the world is concerned, it would be better to adopt no convention at all as regards map colors, than to adopt one carrying with it and promulgating a vicious classification. Uniformity is not worth purchasing at the price of falsification. If the members of the Congress cannot agree upon a plan having the flexibility demanded by the geologic facts, it will be best to limit its action to the local problems involved in the map of Europe. I believe, however, that the necessary flexibility is attainable, and before proceeding to further criticism of the committee scheme I will give the outlines of a plan which appears to me to combine the advantage of flexibility with a number of other desirable qualities.

The plan is founded on the universality of geologic time and the diversity of local geologic histories as expressed in rock systems. Geologic periods are arranged in linear order. Each one adjoins the next and together they constitute continuous geologic time, which we may conceive as represented by a straight line. The stratigraphic systems of a country have likewise an order of succession, and their arrangement is linear. They are not always continuous one with another, but the history recorded by the systems and the breaks between them is continuous and may be represented by a straight line, equal and parallel to that of geologic time. And so for each country. A color scale which shall represent each and all of these parallel lines must be itself linear and continuous, and, fortunately, we have such a scale furnished us in the prismatic spectrum.

I propose, first, that the continuous prismatic spectrum be adopted as the standard universal scale for continuous geologic time. I propose, second, that the conventional time scale, based on the geologic history of Europe, be complemented by a color scale, prismatic but discontinuous. I would assign to

each period, not a certain portion or area of the spectrum, but a specific color defined by its position in the spectrum. This color scale will also apply to the geology of Europe. I propose, third, that the students of each geologic district shall assign to the stratigraphic systems of that district a set of prismatic colors so selected from the spectrum as to properly represent the relation of each system to the time scale, provided that relation is approximately known. Under this rule a system corresponding partly with the Cretaceous and partly with the Jurassic will receive a prismatic color intermediate between those assigned to the Cretaceal and Jural divisions of the time scale. I propose, fourth, that systems whose relations to the standard time scale are not even approximately known be given tentative positions in the time scale and assigned the corresponding colors; and that such provisional colors be distinguished by a special device.

Of this device I will speak later, but before we leave this part of the subject, the capability of the plan to express the facts should be more clearly characterized. Continuous geologic time being equated with the continuous spectral band of light, each period is theoretically equated with a segment of that band including all the hues between certain limits. But, practically, the period is represented in the color scale only by the central hue of the segment, and there is nothing in the nature of this hue to indicate the length of the segment. Similarly each local system is represented only by the hue corresponding to the middle of the equivalent period, considered as a part of the continuous time-scale, and this hue gives no information as to the magnitude of the system or the duration of the corresponding period. When a non-European system is represented on a map with the Devonal color, all that is expressed is that the middle of its period coincides with the middle of the Devonal period; the whole period may equal the Devonal or may be shorter or may be longer. With this limitation the scheme is able to express the exact facts, or the exact state of opinion, in regard to correlation.

I propose, fifth, that the subdivisions of systems be represented, if their number is small, by distinct tones of the hue assigned to the system, and if their number is great, by monochromatic textures. It having been provided that systems shall be distinguished by means of hues, it is now provided that hues shall have no other function. This secures the integrity of the distinction between systems, whatever the minuteness of subdivision.

The idea of using the spectral colors in their proper order is not novel. It has entered into half the plans submitted to the Congress, but each author has introduced other colors also, or

else has undertaken to use the spectrum colors more than once, under the impression that they do not afford the necessary range or variety. This impression is based largely upon the popular meaning of the word color. It is indeed true that if we limit ourselves to those parts of the spectral series which have univocal names, we have only six or seven distinctions; and it is further true that if we have recourse to binomial designations, such as yellowish green and greenish yellow, we obtain rather indefinite conceptions; but to men of science there are better resources than those afforded by the language of every day life. The spectrum has been elaborately studied, and the relations of its dark lines to its colors have been determined. Its wave lengths have, moreover, been measured, and by such means as these we are furnished with three different scales, any one of which is adequate to the precise definition of any hue of the continuous series. What needs to be done is this. When the divisions of the time scale have been decided on, the spectrum must be studied to ascertain the best selection of hues. Their number must, of course, be that of the number of divisions of the time scale, and they must be so chosen that the degree of separateness of adjacent colors shall be everywhere the same, as judged by the normal human eye. Then define each hue by its wave length, or its position in the Kirchhoff scale, and define it also in terms of the best combination of pigments with which it can be approximately reproduced for practical use. It is of course impossible to copy the prismatic colors with accuracy, because the colors of pigments are impure, but this difficulty will not seriously interfere with the employment of the prismatic colors as a standard.

The practical question whether the spectrum will give a sufficient number of hues so far separated from each other as to be distinguishable in all the arrangements occurring on maps has received such consideration as I have been able to give it, and it is my judgment that the maximum number of hues that can safely be used falls somewhere between fifteen and twenty. There will certainly be no difficulty in thus constructing a standard color scale with about a dozen terms.

The employment of the spectral colors in this manner leaves three groups of colors unassigned, the purples, the browns and the grays. If the spectral colors be arranged on the circumference of a circle so that each diameter of the circle connects hues that are complementary, it is found that they occupy the greater part, but not quite all, of the circumference, and the color needed to fill the vacant arc is purple. The hues of purple might then, if deemed necessary, be added to one end or the other of the spectrum, thus increasing the range from which to select colors for the time scale.

My sixth proposition is to assign the browns to volcanic rocks. I would leave the grays unassigned.

It will be observed that no intimation has been given as to whether the violet end of the spectrum should apply to the newest system of strata or the oldest. It must of course be definitely assigned to one or the other, but the particular assignment is a matter of indifference.

The main features of the proposed prismatic scheme have now been set forth and you are fairly entitled to exemption from the minor features, but there is one detail that can hardly be omitted. In one of the main propositions it was provided that some special device should distinguish colors assigned to uncorrelated systems, and I feel it incumbent to show that a suitable device can be found. Of a number that have occurred to me as about equally available, I will mention but a single one—the overprinting, in small dots, widely separated, of the complementary color. The complementary color is selected because it does not disturb the relation of the system-color to the colors of adjacent systems. Bichromatic overprinting produces a hue intermediate between the two hues combined, but the hue midway between a system-color and its complementary color is white or gray, and if only a small amount of the complementary color is added, the system-color becomes merely paler or duller, when viewed from such a distance that the colors blend.

The prismatic color scheme having been constructed for the express purpose of securing a degree of flexibility that will fit it for universal use need not be further compared in that regard with the scheme published by the European map committee. Enough has also been said to show that its superior perspicuity is claimed both for general and for detail maps. A few words will suffice to compare the two systems in other respects.

As regards the expense incurred in the production of general maps, neither scheme has notable advantage, and they are not yet sufficiently developed to permit a comparison as regards the cost of detail maps. Their capability for the production of pleasant color effects can be best judged when maps have been actually made, but it may be said in a general way that the committee's scheme will afford more strong contrasts between adjacent color areas than the prismatic. The maps colored by the former will be relatively lively, those colored by the latter relatively quiet. It is provided by the committee that the volcanic colors shall be not merely red but strong. On a general map volcanic areas cover comparatively small spaces, and strong reds thus disposed will ordinarily add brilliancy; but the detail map of a volcanic district, thus colored, will be disquietingly suggestive of active eruption.

The alphabet of colors for the prismatic scale will be the more easily learned of the two, because it is orderly, and because its order is already familiar in the spectrum. The committee's scheme, however, has some old-fashioned mnemonic features which the prismatic lacks. The green of the Cretaceous is connected with green-sand, the red of volcanic rocks with fire, and the rose of the Archæan with feldspar; and the gray of the Carboniferous mildly suggests the blackness of coal.

In respect to facility of introduction the committee's scheme, being essentially a compromise of existing color scales, has the advantage that to most users it is not entirely novel. The prismatic scheme on the other hand has the advantage of being orderly. It scientifically differentiates the functions of hues and tones, and though each one of its colors may be different from what the individual geologist has previously employed for the indication of the same system, the order of the colors is already familiar to him in another way.

This closes my review of the various works undertaken by the congress. Some of these have been favored, others opposed, and reasons have been given. But there is a general consideration or criterion applicable to all, which has nearly escaped mention, although it is of preëminent importance. When a matter is proposed for regulation by the congress, the first question which should be asked is whether it falls within the legitimate purview of a convention of geologists. It manifestly does not if it belongs to some other science rather than to geology; and objection has on this ground been made against the regulation by our geologic congress of the nomenclatures of paleontology and mineralogy. But not all geologic matters even are properly subject to settlement by convention. This is peculiarly the case with geologic facts. Science is distinguished from the earlier philosophies of mankind by the peculiarity that it establishes its fundamental data by observation. The old philosophies were founded largely upon assumptions, and it was not deemed illogical—perhaps it was not illogical—to appeal to the authority of an assemblage of experts for the establishment of fundamental assumptions. But for science it is not merely illogical, it is suicidal, to establish facts in any other way than by observation. No vote of the most august scientific body can possibly establish a fact, and no vote can have any weight against a good observation.

Now the entire science of geology, using the phrase in a strict sense, is constituted by the aggregation and arrangements of facts, and none of its results can be rendered more true, or be more firmly established, or be prevented from yielding to contradictory facts, by conventional agreement. A class-

ification, if it has any value whatever, is merely a generalized expression of the facts of observation, and is outside the dominion of the voter. If it comprises all the essential facts, its sufficiency will eventually be recognized, whether its authority is individual or collective. If it does not comprise them, it will inevitably be superseded, by whatever authority it may have been instituted. For this reason I am opposed to the classification by the congress of the sedimentary formations, and likewise to the classification of the volcanic rocks, and I also regard it as ill-advised that the congress undertook the preparation of a map of Europe, for that—if more than a work of compilation—is a work of classification.

If we examine the other undertakings of the congress—the definition and gradation of taxonomic terms, the systematization of terminations, the selection of a scale of colors for geologic maps, and the selection of other conventional signs for the graphic expression of geologic phenomena—we find that they all belong to the means of intercommunication of geologists. They affect only the verbal and graphic technical language of the science. Of the same nature is the arbitrary time scale whose preparation I favor,—a conventional terminology for the facts of correlation. So we may say in general, that the proper function of the congress is the establishment of common means of expressing the facts of geology. It should not meddle with the facts themselves. It may regulate the art of the geologist, but it must not attempt to regulate his science. Its proper field of work lies in the determination of questions of technology; it is a trespasser if it undertakes the determination of questions of science. It may decree terms, but it must not decree opinions.

ART. XLIX.—*On the Existence of certain Elements, together with the discovery of Platinum, in the sun. Contributions from the Physical Laboratory of Harvard University;* by C. C. HUTCHINS and E. L. HOLDEN.

[From the Proceedings of the American Academy of Arts and Sciences, vol. xxiii.]

LATE in the fall of 1886 it was decided by the writers, who were then at work in the Physical Laboratory of Harvard University, to attempt a revision of some of the previous work in regard to the chemical constitution of the sun, as well as to discover, if possible, new facts bearing on the same subject. For the purpose of this investigation a magnificent diffraction grating, made by Professor Rowland of Baltimore, was kindly

placed at our disposal by Professor John Trowbridge, under whose supervision and directions the subsequent work has been done.

After some delay caused by the mounting of the grating and its attachments, work was begun early in January, 1887, but, owing to bad weather and other hindrances, was not regularly and systematically prosecuted till somewhat later.

The grating used is of speculum metal with a ruled surface measuring 6 inches by 2, having 14,438 lines to the inch. It is concave, its radius of curvature being 21½ feet, and is mounted according to Professor Rowland's method. Suffice it to say, that the method is such that, by simply rolling the camera along an iron track, it passes not only from one part of the spectrum to another, but also to the spectra of different orders, at the will of the operator. As the distances on this track are proportional to the relative wave-lengths of the lines that fall successively on a given point in the camera, it is easy, by means of a suitable scale of equal parts placed beside the track, to set the center of the photographic plate instantly within a single wave-length of any given line in the spectrum.

And here let us parenthetically state that all our wave-lengths are those given by Professor Rowland's photographic map of the solar spectrum, the position of every line referred to being carefully identified upon the map, and its absolute wave-length thus determined. Although some of the negatives contain many lines too faint to show on the map, yet we feel confident that our numbers correspond in all cases to those of the map within one-tenth of a wave-length.

The light is brought into the room by means of a *porte lumière* and then sent through the slit after total reflection by a right-angled prism. Before striking the prism it passes through a cylindrical lens, which condenses it to a band of light about 2 inches long and ⅛ inch wide. The jaws of the slit move equally in opposite directions, so that, however widely they may be opened, no lateral displacement of lines can result from this cause.

Directly in front of the slit is placed a large tin lantern containing an electric lamp; the image of the arc can be brought exactly upon the slit by means of an adjustable lens in the front of the lantern. In the lower carbon of the lamp is made a cup-shaped cavity, which is filled with the substance a spectrum of which is desired. It is not at all necessary that this be in the form of a metal, for any ordinary compound is at once reduced by the intense heat and the presence of carbon vapor to the metallic state.

The plan of working has been as follows. The apparatus being arranged as described, the sunlight is admitted and the

desired portion of solar spectrum photographed upon the upper half of the plate; then the sunlight is excluded by a shutter, and the image of the electric arc containing the proper metal is allowed to fall upon the slit, and its spectrum photographed on the lower half of the plate. (Most of the plates used were those made by the M. A. Seed Co., and were cut to the size of 8 inches by 2. The most sensitive plates were obtained, and even then we found the required time of exposure for some parts of the spectrum inconveniently long.)

In order to effect the exposure of either half of the plate at will, we placed directly in front of the camera an opaque screen, in which was a rectangular opening one half the size of the plate. By turning a handle, this screen is raised or lowered without the slightest disturbance of camera or plate. The metallic spectrum, being thus photographed immediately below the solar spectrum, can be compared with it at leisure.

These spectra are then examined with the aid of a glass magnifying about ten diameters, and any concidences between solar and metallic lines carefully noted according to their wave-lengths. In order to eliminate any personal error, they are examined by both observers separately, and their results afterwards compared.

To eliminate errors arising from suspected impurites of materials, as also from the impurities known to exist in the carbons employed, we took what we called "comparison photographs." For these, we placed in the carbon cup a portion of the substances known or suspected to be present as impurities in our metal, and then photographed the spectrum thus given on the upper half of the plate; a piece of the metal under experiment was then placed in the lamp, and the spectrum photographed on the lower part of the plate. Any lines due to impurities would then extend entirely across the plate, while those of the pure metal would extend only half way. In addition to this precaution we consulted all accessible tables and plates as to the position of known lines of metallic spectra, and also compared together all our photographs of the same region. If all of these tests left any doubt as to the origin of a given line, it was at once subjected to special investigation until all doubt was removed.

The dispersion given by the apparatus in the order of spectrum in which we worked is such that a single wave-length occupies on the negative a space of 1·12 mm. This makes the distance between the lines D_1 and D_2 6·7 mm., while the length of spectrum from A to H is about 4·1 m. With so great dispersion it would hardly be possible to mistake the position of a line by any very considerable amount, or to confound neighboring lines belonging to different metals.

For reasons readily apparent, it was found so difficult to photograph under high dispersive power those parts of the spectrum not lying between wave-length 3600 and wave-length 5000, that our photographic work was done chiefly within those limits. It was, however, supplemented in many cases by eye observations in other portions of the spectrum.

We are convinced that there is much in the whole matter of coincidences of metallic and solar lines that needs re-exam in tion; that something more than the mere coincidence of two or three lines out of many is necessary to establish even the probability of the presence of a metal in the sun. With the best instruments the violet portion of the solar spectrum is found to be so thickly set with fine lines, that, if a metallic line were projected upon it at random, in many places the chances for a coincidence would be even, and coincidences could not fail to occur in case of such metals as cerium and vanadium which give hundreds of lines in the arc.

Moreover, a high dispersion shows that very few lines of metals are simple and short, but, on the contrary, winged and nebulous, and complicated by a great variety of reversal phenomena. A "line" is sometimes half an inch wide on the photographic plate, or it may be split into ten by reversals.

At first, we believed that these reversals were due to defects in the ruling of the grating, but we are convinced that they are true phenomena from the following experiments. 1st. The wings continue when various portions of the grating are covered. 2d. They are the same in three successive orders of spectra. 3d. They are very different in different metals, and in some are not seen at all. 4th. We arranged a flat grating, with collimator and projecting lens, each of five feet focus, and found that with this apparatus the same phenomena appeared.

On pages 87 and 88 of "The Sun," Professor Young gives a list of elements in the sun according to the best authorities, which is followed by a list of doubtful elements. Some of these we have examined with the following results:

Cadmium.—The coincidence of the two lines given by Lockyer at wave-lengths 4677 and 4799 is perfect. These are the only cadmium lines near, and the sun lines in the vicinity are not numerous.

Lead.—The evidence for lead, due to Lockyer, is based upon three lines at 4019·7, 4058·2 and 4061·8. We have photographed these lines with the sun many times. They are broad and nebulous, and often several times reversed. Lines in solar spectrum numerous and faint. 4019·7 and 4058·2 certainly do not coincide. 4061·8 is very difficult to pronounce upon; it may coincide.

Cerium, *Molybdenum*, *Uranium* and *Vanadium.*—These four

metals may be classed together. Lockyer finds four coincidences each for molybdenum and vanadium, three for uranium, and two for cerium. The arc spectrum of each is characterized by great complexity and vast numbers of lines. So numerous are the lines in fact, that often on the photographs the total space occupied by them is greater than the space not so occupied. A plate ten inches long may contain a thousand or so. Evidently coincidences between these and solar lines cannot fail to occur as matters of chance, and therefore prove nothing. One can easily count a hundred or so such coincidences without the slightest conviction that the connection is other than fortuitous. Of course all this is nothing against the probability of these metals being in the sun; but at the same time those peculiarities of grouping, strength of lines, and other characteristics which occur in the case of iron and other spectra, and which alone can serve as evidence in such cases, are conspicuously absent.

Among the metals whose existence in the solar atmosphere has seemed probable, we have examined the following:

Bismuth.—The line of the above metal at 4722·9, the only line of bismuth in the arc in that whole region, coincides perfectly with the more refrangible of a very faint pair of solar lines.

Tin.—The solitary tin line at 4525, thought by Lockyer to coincide, falls directly between two fine lines in the solar spectrum.

Silver.—Lockyer mentions a certain possibility of silver in the solar atmosphere from the apparent agreement of two of its nebulous lines with solar lines. One of these we have never been able to find in the course of many photographs of the region in which it is given by him.

We find seven lines of silver between 4000 and 4900. Of these seven, three are what Thalen calls nebulous; so broad and hazy that their true positions cannot be determined with much accuracy. These lie at about 4055·5, 4063·6, and 4212. A fourth line at 4023 is of the same general character, but has a sharp reversal which agrees with a solar line. The remaining three lines are represented in the sun, and are given by Thalen in the spark spectrum of the metal.

4476·2. Very strong line; nebulous on lower edge. Sun line strong. (Thalen, 4475.)

4668·8. Strong, solitary line. (Thalen, 4666·5.)

4874·3. Fairly strong. (Thalen, 4874.)

Thus, between the limits given above, every line of silver, as far as can be determined, coincides with a solar line.

Potassium.—We could find but two lines of potassium, the same that were examined by Lockyer, 4044·5 and 4048·35.

Each line is reversed four times, which increases the difficulty of locating them exactly. 4048·35 seems to agree with a solar line. The solar line near 4044·5 is very faint, and it is next to impossible to decide the question of an agreement.

Lithium.—The blue line of lithium presents a curious case. The very broad and nebulous line has a rather sharp reversal near the center, and somewhat toward the lower edge a broader and less clearly defined reversal. Both these reversals agree with solar lines at 4602·5 and 4603·2. It is possible that one of the reversals may be due to the presence of some other substance, say calcium; but if that were true, it would seem that both reversals would be nearly, if not quite, obliterated. Further experiment may clear the matter up. 4603·2 is given to iron by Thalen.

Platinum.—As far as we can learn, no evidence has hitherto been offered to show the occurrence of this metal in the solar atmosphere. We were somewhat surprised, therefore, upon meeting with coincidences. Between 4250 and 4950 we find 64 lines of platinum, sixteen of which agree with solar lines. The latter are at the following places:—

4291·10	4481·85
4392·00 (Thalen 4389·4)	4552·80 (Thalen 4551·8)
4430·40	4560·30
4435·20	4580·80
4440·70	4852·90 (Thalen 4851·5)
4445·75 (Thalen 4442·0)	4857·70
4448·05	4899·00
4455·00	4932·40

We have taken all possible care to make this statement accurate, and to admit no lines about which there seems to be any question. There are seven other lines not included in the list, the probability of agreement of which is at least as good as that upon which potassium is admitted.

In all these experiments everything has been done to bring out and show upon the photograph as much as possible. The lamp, constructed for the purpose and fed by a powerful dynamo, gave an arc from a half to three-fourths of an inch long, and with a long flame and so intense a heat that it could be worked for but a few minutes at a time. Any one who has carried out a series of experiments like this is alone competent to appreciate the great labor and the endless difficulties and perplexities that attend them.

Our thanks are especially due to Dr. Wolcott Gibbs for his hearty encouragement, and for the use of valuable apparatus and chemicals.

ART. L.—*The Flora of the Coast Islands of California in relation to recent changes of Physical Geography;* by JOSEPH LECONTE.

SOME of the results reached by Mr. E. L. Greene in his studies of the flora of the islands off the coast of Southern California* have deeply interested me, because I believe their explanation may be found in geologically recent changes in the physical geography of California.

These remarkable islands, 8 or 10 in number, are strung along the coast from Point Conception southward, and separated from the mainland by a sound 20–30 miles wide. They are of considerable size (the largest being about 200 square miles in extent), and vary in height from 1,000 to 3,000 feet. They have all the characteristics of continental islands, and are undoubtedly outliers of the mainland, at one time connected with it, but now separated by subsidence of the continental margin. They may be regarded as the highest points of an old coast range outside of the present coast range, the broad valley between the two being now covered with water. Moreover, the date of the separation may be determined with certainty. That they were connected with the mainland during the later Pliocene and early Quaternary is proved by the fact that remains of the mammoth have been found on Santa Rosa, the largest and one of the farthest off of them.† *They were, therefore, undoubtedly separated during the Quaternary Period.*

The main points in Mr. Greene's paper with which we are here concerned are the following:

1. Out of 296 species of plants collected by him on the island of Santa Cruz, no less than 48 are entirely peculiar to these islands, and 28 peculiar to Santa Cruz itself.

2. Of the remaining 248 species nearly all are *distinctively Californian*—that is, species peculiar to California are very abundant, while common American species, *i. e.*, those common to California and other parts of North America, are very few and rare. The flora as a whole, therefore, may be regarded as distinctively Californian, with the addition of a large number of species wholly peculiar to the islands.

3. A number of rare species found in isolated patches, and, as it were, struggling for existence, in the southern counties—San Diego and San Bernardino—are found in *great abundance and very thriving condition on the islands.*

* Studies in the Botany of California and Parts Adjacent, VI. E. L. Greene. I—Notes on Botany of Santa Cruz Island. Bull. 7, Cal. Acad. Sci.

† Proc. Cal. Acad. Sci., vol. v, 152.

4. *Lavatera*, a remarkable malvaceous genus of which 18 species are known in the Mediterranean region, and one from Australia, but *not a single species on the American Continent, is represented on these islands by four species.* This is certainly a most remarkable and significant fact.

Such are the facts. I account for them as follows:

California, especially the region west of the Sierra Nevada, is geologically very recent. The Sierra region was reclaimed from the sea at the beginning of the Cretaceous, and the coast region as late as the beginning of the Pliocene. When first emerged the coast region was of course colonized from adjacent parts. This colonization was probably mainly from Mexico, either directly or through the Sierra region; for the distinctively Californian plants, though peculiar, are more like those of Mexico than any other. Whencesoever it may have been colonized, however, the environment was sufficiently peculiar, the isolation sufficiently complete, and the time has been sufficiently long to make a very distinct flora. According to Wallace it is one of the primary divisions of the Nearctic Region.

During the late Pliocene and early Quaternary, as already seen, the islands were still a part of the mainland, and the whole was occupied by the same flora, viz: the distinctively Californian (with some differences doubtless), now found in both, together with the peculiar island-species.

During the oscillations of the Quaternary the then westernmost coast range was separated by subsidence, and has remained ever since as islands. Simultaneously with, or after, this separation, came the invasion of northern species, driven southward by glacial cold. Then followed the mingling of invaders with the natives, the struggle for mastery, the extermination of many (viz: the peculiar island species), and perhaps the slight modification of all, and the final result is the California flora of today. But the island flora was saved from this invasion by isolation, and therefore far less changed than the flora of the mainland, *i. e.*, the invading species are mostly wanting, and many species survived there which were destroyed, or else modified into other species, on the mainland, and the remainder probably less modified than on the mainland. The flora of these islands, therefore, represents somewhat nearly the character of the flora of the whole country during the Pliocene times. Some modification they have doubtless suffered, but the time has been too short for any great change in the absence of severe competition.

The question naturally arises, "How is it that with a separation of only 20–30 miles the two floras—insular and mainland—have not become entirely similar by mutual colonization?" The prevailing winds being landward would, I sup-

pose, largely prevent the colonization of common American forms on the islands, although some such colonization has in fact taken place. But with the prevailing winds in this direction, why have not all the peculiar island species been long ago colonized on the mainland? According to the view above presented the answer is evident. These peculiar species did once inhabit the mainland, and have been either destroyed or transformed by the struggle with invaders. They are therefore *weaker* species. The same unfitness which made them succumb then, still forbids their successful colonization. This brings me to the next point.

There are quite a number of rare and peculiar forms found struggling for existence in the southern counties which are found very abundant on the islands. This certainly looks like the beginning of colonization. This is indeed Mr. Greene's view, and is rendered all the more probable by the fact that the ocean currents probably drift in that direction. But there is at least another explanation suggested by the view above presented. These may be, and probably are, *remnants* of Pliocene indigenes still undestroyed, but ready to perish. From this point of view their place far south is just what we might expect, for the main invasion was from the north.

But there is still a last point to be explained. *Lavateras* are unknown in the New World, except on these islands, where there are four species. But they are found in the Old World, in the Mediterranean region and in Australia. Mr. Greene suggests, as a possible explanation, *a former connection of these islands with some other continent.* I think not. The substantial permance of continental land masses and oceanic basins, with only marginal changes, at least during later geological times—taken together with the comparative recency of the flora of California—renders this explanation extremely improbable. The above presented view suggests another and far more probable explanation.

The existence of *Lavateras* in such widely separated localities as Australia, the Mediterranean region and the coast islands of California, shows unmistakably that existing species are but remnants of an old, once very abundant and widely spread genus, with numerous species. They are now dying out. They have been mostly destroyed and replaced by newer and stronger forms. I conclude, therefore, that in Pliocene times several species of *Lavatera* existed all over the coast region of California, but probably mostly in the then coast range, viz: the islands; for they love the sea coast. They have all been destroyed by change of environment, physical and organic, except those isolated on the islands and thus saved from the effects of invasion.

Readers of Mr. Wallace's "Island Life" will at once see the analogy between this explanation of the flora of our coast islands and Mr. Wallace's explanation of the mammalian fauna of Madagascar. The mammalian fauna of Africa, south of Sahara, consists of two very distinct groups—the one *indigenous* or descendants of Tertiary indigenes, and *remotely* resembling that of Madagascar, the other evidently *foreign* and resembling that of *Eurasia in Miocene and Pliocene times.* During Tertiary times Africa was isolated from Eurasia, but united with Madagascar, and the whole inhabited by a peculiar fauna, characterized by lemurs, insectivores, etc., which we have called indigenes. About middle Tertiary times, Madagascar was separated, and immediately divergence between the two faunas commenced. In the later Tertiary and early Quaternary, the barrier which separated Africa from Eurasia was removed, and the great Eurasian animals invaded Africa, and immediately became the dominant type. In the struggle which ensued, many species, especially of the weaker indigenes, were destroyed, and all on both sides modified. The result is the African fauna of to-day. Madagascar was saved from this invasion by isolation. The fauna there consists of the greatly modified descendants of the African Tertiary indigenes, but far less modified than their congeners in Africa. In the fauna of Madagascar, therefore, we have the nearest approach to the Tertiary indigenes of both.

The difference between the two cases is this: In the case of Madagascar the separation has been very long. The extreme peculiarity of its fauna is the result partly of progressive *divergence* and partly of *many forms saved by isolation.* In the case of the coast islands of California, the separation is comparatively recent—there has not been time enough for very great divergence by modification. The peculiarity of its flora is due almost wholly to species saved by isolation.

In conclusion I would say, that this short paper is intended merely as an incentive to future investigation and pointing in the direction which it ought to take. Before the views above presented can be definitely established, there must be further investigations, first, on the relation of the island flora to that of the mainland; second, on the relation of the flora of California to that of adjacent parts from which it may have been originally colonized; third, and especially, must we have fuller knowledge of the indigenous flora of California in Pliocene times.

ART. LI.—*Determination of "prevailing wind direction;"* by H. ALLEN HAZEN.

VARIOUS methods have been adopted for the graphic representation of the prevailing wind direction. Perhaps the simplest of these consists in drawing radial lines for each of the eight principal points of the compass and making the length of each line correspond to the number of times the wind has blown from that direction. A broken line joining the ends of these would enclose an area, and the portions of this area between the radials would indicate approximately the frequency of the wind. If the winds were not of the same velocity from all points, this could be indicated by figures on each line denoting the mean velocity from each direction. The difference would be inappreciable in the United States, and in fact wherever there is a difference the velocity will be greater in the line of the prevailing direction, so that, allowing for velocity, we would simply intensify the mean direction. In no case would there be any error in the mean direction ensuing from a neglect of a slight variation in the velocity.

Lambert's formula.

Perhaps the best method of getting this quantity is by means of Lambert's formula. The ordinary computation of this formula is exceedingly tedious, especially where several thousand computations are to be made. I have prepared very simple tables, for my own use, which do away with the use of logarithms and enable any one at a glance to take out the quantity sought. The whole process is a simple mechanical one and a child can perform the work without difficulty. It has seemed wise to prepare these tables for wider use, because, as the science of meteorology advances the demand is for increased accuracy in its results. The examination of any monthly mean chart with wind directions accurately projected upon it will show distinctly the usual law of circulation of winds about high and low pressures, and where the winds do not seem to follow this law it can be inferred that there is some local peculiarity which affects the wind. These tables are specially commended to voluntary observers of the weather for the computation of their mean wind direction.

We have Lambert's formula as follows:

$$\tan A = \frac{\text{E–W} + (\text{NE–SW}) \cos 45^\circ + (\text{SE–NW}) \cos 45^\circ}{\text{N–S} + (\text{NE–SW}) \cos 45^\circ - (\text{SE–NW}) \cos 45^\circ}$$

In which N, NE, E, etc., represent the number of times the wind has been observed from that direction during the period

under discussion. The simplest method of application would be to prepare a form in which to enter the observations in an order most suited for computation. Strict attention must be paid throughout to the algebraic signs. To those who are unaccustomed to algebraic processes the following rules will be well worth remembering. For algebraic addition — if the signs of the quantities are *alike* add them; if *unlike* subtract them and give the result the sign of the larger quantity, e. g. $3+4=7$, $-16+4=-12$. For subtraction—change the sign of the second quantity and proceed as in addition, e. g. $(+3)-(+4)=-1$, $(-16)-(+4)=-20$. The form to be used is as follows:

a	b	c	d	e	f	g	h	i	k	l	m	n	o	p	q	r	s		Direction.
E	W	N	S	NE	SW	SE	NW	NE-SW	SE-NW	$i\times$ cos 45°	$k\times$ cos 45°	E-W	$l+m$	N-S	$l-m$	$o+n$	$p+q$	$r \div s$	
2	12	21	26	13	9	0	10	4	—10	2·8	—7·1	—10	—4·3	—5·0	9·9	—14·3	4·9	19	N 71° W

Fill in the columns a to h with the number of times the wind has blown from the eight points of the compass. The remaining computations are indicated at the head of each column. The values in (l) and (m), i and k, multiplied by cos 45°, may be taken from Table I. Having determined r and s, we have reduced the winds from the eight points to two at right angles to each other, or we have a right-angled triangle in which we have given the base and perpendicular, the tangent of the true angle of the wind being the one divided by the other. Winds from N and E are regarded as positive $+$. The quadrant in which the angle lies is obtained as follows: $\frac{-r}{+s}=$ NW : $\frac{+r}{-s}=$ SE : $\frac{+r}{+s}=$ NE : $\frac{-r}{-s}=$ SW. In writing the angle, N. or S. should *always* be placed first. The value of the angle may be immediately taken out of the table "Values of A" when we have r and s given. If either or both of these be greater than 160, divide both by such a number as will make the larger, 160 or less. Find the smaller number in the top horizontal row of figures, the other in the vertical row at the left. The number at the intersection of the two will be the angle sought, unless s is smaller than r. If so, subtract the number from 90°. In the example given, $r=-14·3$; $s=4·9$ at the intersection of 49 and 145 we find 19°; since s is the smaller we must subtract 19° from 90° and we have $\frac{-r}{+s}=$N 71° W. It will be readily seen that in entering the final table we may ignore the decimal points, although with a good deal more trouble we could have gotten the same result by entering with 4·9

and 14·3. If we should have 5 and 14·3 it would be much better to multiply the whole number by 10 and enter the table with 50 and 143, i. e., the larger the numbers used, provided they are within the limits of the table the easier the computation.

The instructions in this paper have been prepared by Mr. R. A. Clark.

June 7, 1887.

TABLE I.—*Multiples of cosine* 45° (·7071).

	Units.										
Tens.	0	1	2	3	4	5	6	7	8	9	Tens.
0	0·0	·7	1·4	2·1	2·8	3·5	4·2	4·9	5·7	6·4	0
10	7·1	7·8	8·5	9·2	9·9	10·6	11·3	12·0	12·7	13·4	10
20	14·1	14·8	15·6	16·3	17·0	17·7	18·4	19·1	19·8	20·5	20
30	21·2	21·9	22·6	23·3	24·0	24·7	25·5	26·2	26·9	27·6	30
40	28·3	29·0	29·7	30·4	31·1	31·8	32·5	33·2	33·9	34·6	40
50	35·4	36·1	36·8	37·5	38·2	38·9	39·6	40·3	41·0	41·7	50
60	42·4	43·1	43·8	44·5	45·3	46·0	46·7	47·4	48·1	48·8	60
70	49·5	50·2	50·9	51·6	52·3	53·0	53·7	54·4	55·2	55·9	70
80	56·6	57·3	58·0	58·7	59·4	60·1	60·8	61·5	62·2	62·9	80
90	63·6	64·3	65·1	65·8	66·5	67·2	67·9	68·6	69·3	70·0	90
100	70·7	71·4	72·1	72·8	73·5	74·2	75·0	75·7	76·4	77·1	100
110	77·8	78·5	79·2	79·9	80·6	81·3	82·0	82·7	83·4	84·1	110
120	84·9	85·6	86·3	87·0	87·7	88·4	89·1	89·8	90·5	91·2	120
130	91·9	92·6	93·3	94·0	94·8	95·5	96·2	96·9	97·6	98·3	130
140	99·0	99·7	100·4	101·1	101·8	102·5	103·2	103·9	104·7	105·4	140
150	106·1	106·8	107·5	108·2	108·9	109·6	110·3	111·0	111·7	112·4	150

In using this table find the tens and hundred of the number to be multiplied by cos 45° in the left hand column and the units in the upper horizontal line. The product will be found at the intersection of the horizontal and vertical lines from these. For example, 148 × cos 45° at the intersection of 140 and 8 we find 104·7 answer.

Values of the angle A.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
10	6	11	17	22	27	31	35	39	42	45															
15	4	8	11	15	18	22	25	28	31	34	36	39	41	43	45										
20	3	6	9	11	14	17	19	22	24	27	29	31	33	35	37	39	40	42	44	45					
25	2	5	7	9	11	13	16	18	20	22	24	26	27	29	31	33	34	36	37	39	40	41	43	44	45
30	2	4	6	8	9	11	13	15	16	18	20	22	23	25	27	28	30	31	32	34	35	36	37	39	40
35	2	3	5	7	8	10	11	13	14	16	17	19	20	22	23	25	26	27	28	30	31	32	33	34	36
40	1	3	4	6	7	9	10	11	13	14	15	17	18	19	21	22	23	24	25	27	28	29	30	31	32
45	1	3	4	5	6	8	9	10	11	13	14	15	16	17	18	20	21	22	23	24	25	26	27	28	29
50	1	2	3	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	25	26	27
55	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	24
60	1	2	3	4	5	6	7	8	9	9	10	11	12	13	14	15	16	17	18	18	19	20	21	22	23
65	1	2	3	4	4	5	6	7	8	9	10	10	11	12	13	14	15	15	16	17	18	19	19	20	21
70	1	2	2	3	4	5	6	7	7	8	9	10	11	11	12	13	14	14	15	16	17	17	18	19	20
75	1	2	2	3	4	5	5	6	7	8	8	9	10	11	11	12	13	13	14	15	16	16	17	18	18
80	1	1	2	3	4	4	5	6	6	7	8	9	9	10	11	11	12	13	13	14	15	15	16	17	17
85	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13	14	14	15	16	16
90	1	1	2	3	3	4	4	5	6	6	7	8	8	9	9	10	11	11	12	13	13	14	14	15	16
95	1	1	2	2	3	4	4	5	5	6	7	7	8	8	9	10	10	11	11	12	12	13	14	14	15
100	1	1	2	2	3	3	4	5	5	6	6	7	7	8	9	9	10	10	11	11	12	12	13	13	14
105	1	1	2	2	3	3	4	4	5	5	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13
110	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13
115	0	1	1	2	2	3	3	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12
120	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12
125	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11
130	0	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11
135	0	1	1	2	2	3	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	10
140	0	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10
145	0	1	1	2	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	9	9	9	10
150	0	1	1	1	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	9	9	9
155	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	7	7	8	8	8	9	9
160	0	1	1	1	2	2	2	3	3	3	3	4	4	5	5	5	5	6	6	7	7	8	8	9	9
165	0	1	1	1	2	2	2	3	3	3	3	4	4	5	5	5	5	6	6	7	7	7	8	8	9
170	0	1	1	1	2	2	2	3	3	3	3	4	4	5	5	5	5	6	6	7	7	7	8	8	8
175	0	1	1	1	2	2	2	3	3	3	3	4	4	5	5	5	5	6	6	7	7	7	8	8	8
180	0	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8
185	0	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8
190	0	1	1	1	2	2	2	2	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	8
195	0		1	1	1	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	6	7	7	7	7
200	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7	7
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
10																									
15																									
20																									
25																									
30	41	42	43	44	45																				
35	37	38	39	40	41	41	42	43	44	45															
40	33	34	35	36	37	38	39	40	40	41	42	43	44	44	45										
45	30	31	32	33	34	35	35	36	37	38	39	39	40	41	42	42	43	44	44	45					
50	27	28	29	30	31	32	33	33	34	35	36	37	37	38	39	39	40	41	41	42	43	43	44	44	45
55	25	26	27	28	29	29	30	31	32	32	33	34	35	35	36	37	37	38	39	39	40	41	42	42	43
60	23	24	25	26	27	27	28	29	30	30	31	32	32	33	34	34	35	36	36	37	37	38	39	39	40
65	22	23	23	24	25	25	26	27	28	28	29	30	30	31	32	32	33	33	34	35	35	36	36	37	38
70	20	21	22	23	23	24	25	25	26	27	27	28	28	29	30	30	31	32	32	33	33	34	34	35	36
75	19	20	20	21	22	22	23	24	24	25	26	26	27	27	28	29	29	30	30	31	32	32	33	33	34
80	18	19	19	20	21	21	22	22	23	24	24	25	25	26	27	27	28	28	29	29	30	30	31	31	32
85	17	18	18	19	19	20	21	21	22	22	23	24	24	25	25	26	26	27	27	28	28	29	29	30	30
90	16	17	17	18	18	19	20	20	21	21	22	22	23	23	24	24	25	26	26	27	27	28	28	29	29
95	15	16	16	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26	27	27	28
100	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26	27
105	14	14	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	25
110	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20	20	21	22	23	23	23	24	24	24	24
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120	12	13	13	14	14	14	15	15	16	16	17	17	18	18	18	19	19	20	20	21	21	21	22	22	23
125	12	12	13	13	13	14	14	15	15	16	16	16	17	17	18	18	19	19	19	20	20	21	21	21	22
130	11	12	12	13	13	13	14	14	15	15	15	16	16	17	17	18	18	18	19	19	19	20	20	21	21
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165	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	14	15	15	16	16	16	17	17
170	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	14	15	15	15	16	16	16
175	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	13	14	14	14	14	15	15	16	16
180	8	9	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	13	14	14	14	14	15	15	16
185	8	8	9	9	9	10	10	10	11	11	11	11	12	12	12	12	13	13	13	14	14	14	14	15	15
190	8	8	8	9	9	9	10	10	10	11	11	11	11	12	12	12	12	13	13	13	14	14	14	14	15
195	8	8	8	9	9	9	9	10	10	10	11	11	11	11	12	12	12	12	13	13	13	13	14	14	14
200	7	8	8	8	9	9	9	9	10	10	10	11	11	11	11	11	12	12	12	13	13	13	13	14	14
	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50

Values of the angle A—continued.

	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98
55	42	43	44																						
60	40	41	42	43	44	45																			
65	38	39	40	41	42	43	44	45																	
70	36	37	38	39	40	41	42	42	43	44	45														
75	34	35	36	37	38	39	40	40	41	42	43	44	45												
80	32	33	34	35	36	37	38	39	39	40	41	42	43	44	44	45									
85	30	31	32	33	34	35	36	37	38	39	40	40	41	42	43	43	44	44	45						
90	29	30	31	32	33	34	35	35	36	37	38	39	39	40	41	42	42	43	44	44	45				
95	28	29	30	31	31	32	33	34	35	36	36	37	38	39	39	40	41	41	42	43	43	44	45		
100	27	27	28	29	30	31	32	33	33	34	35	36	37	37	38	39	39	40	41	41	42	43	43	44	44
105	25	26	27	28	29	30	31	31	32	33	34	34	35	36	37	37	38	39	39	40	41	41	42	42	43
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120	23	23	24	25	26	27	27	28	29	30	30	31	32	32	33	34	34	35	36	36	37	37	38	39	39
125	22	23	23	24	25	26	26	27	28	29	29	30	31	31	31	33	33	34	35	35	36	36	37	37	38
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175	16	17	17	18	18	19	19	20	20	21	22	22	23	23	24	25	25	26	26	27	27	28	28	29	29
180	16	16	17	17	18	18	19	20	20	21	21	22	22	23	23	24	24	25	26	26	27	27	28	28	29
185	15	16	16	17	17	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26	27	28	28
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195	14	15	15	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26	27
200	14	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26

	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160
100	45																														
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110	42	43	43	44	44	45																									
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155	33	33	34	34	35	35	36	36	37	37	38	38	39	39	40	40	40	41	41	42	42	42	43	43	44	44	44	45			
160	32	33	33	34	34	35	35	35	36	36	37	37	38	38	39	39	39	40	40	41	41	42	42	42	43	43	44	44	44	45	45
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185	28	29	29	30	30	31	31	32	32	33	33	33	34	34	35	35	35	36	36	37	37	37	38	38	39	39	40	40	40	41	41
190	28	28	29	29	30	30	31	31	31	32	32	33	33	34	34	34	35	35	36	36	36	37	37	38	38	38	39	39	39	40	40
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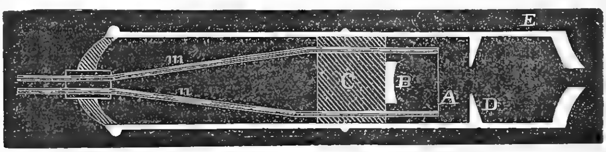
200	27	27	27	28	28	29	29	30	30	31	31	32	32	32	33	33	33	34	34	35	35	35	36	36	37	37	37	38	38	38	39

Art. LII.—*A new instrument for the measurement of Radiation*; by C. C. Hutchins.

The difficulties which attend the use of the thermo-pile as an accurate measurer of radiations, are familiar to all who have had any experience with that instrument. The slowness of its indications, and the long time required for it to return to zero, are defects which entirely unfit it for many delicate experiments.

It occurred to the writer that sensitiveness to radiation might as well be secured by employing a very thin thermal-junction with some condensing arrangement, as by the use of several pairs of stout bars, as in the ordinary thermo-pile; for the thin junction would be heated to a much higher temperature than a thick one by a given quantity of heat, and have the great advantage of quickly parting with its heat and returning to the temperature of the surrounding atmosphere.

The instrument is constructed upon these principles as follows: A tube of vulcanite ten inches long, two and a half inches in diameter, is stopped near the middle by a plug of wood. The tube is made separable, and this plug serves to unite its two halves as well as to support the working parts. Through the plug pass two small copper rods projecting about an inch above the plug toward the front of the instrument, and passing out through its back, where they serve to attach wires extending to a galvanometer.



E, tube of vulcanite; C, plug of wood; *m*, *n*, copper rods; A, thermal junction; B, concave mirror; D, stop.

The thermal junction is made by uniting with hard solder a bit of watch-spring and a bit of flattened copper wire. The whole is then worked to a ribbon 1^{mm} wide, $\cdot 03^{mm}$ thick and 25^{mm} long. The two ends of this ribbon are then soldered to the two copper rods so that the junction may be midway between them.

A concave mirror of glass, silvered upon first surface, is so secured upon the plug that the junction is exactly at its focus. The front of the tube is provided with an opening of any convenient size, and stops to limit the diameter of the entering ray.

The accompanying sketch will make the details clear. Its working has been very satisfactory. It requires no longer to return to zero than for the galvanometer needle to come to rest, and is correspondingly rapid and dead beat in its action. It is much more sensitive than a thermo-pile of the same exposed area.

An instrument in actual use having an opening of 8^{mm} deflects its galvanometer 30 divisions of its scale when the hand is held a foot from the opening. A lighted match at six feet drives the needle around to its stop.

Bowdoin College, Brunswick, Me., Nov. 8, 1887.

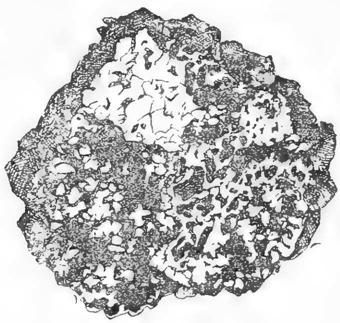
Art. LIII.—*On some American Meteorites;* by George F. Kunz. (With Plate X.)

1. *The Taney Co., Missouri, Meteorite.*

During June 1887 a meteoric mass came into my possession and through the kindness of Miss Hattie Payne, of Lamar, Ark., I learned that it was taken about thirty years before from a spot in latitude 36° 35′ north and longitude 93° 12′ west of Greenwich, near Miney, Taney Co., Missouri, eleven miles S.E. of Forsyth and over sixty miles from Limestone Valley, Ark. Miss Payne also stated that about thirty years ago a meteorite passed over the boundary line between Arkansas and Missouri and was supposed to have fallen near by. After considerable search it was believed to have been located on a farm eleven miles S.E. of Forsyth, whence it was taken sixty miles to a farm in Limestone Valley, Newton Co., Arkansas, on the supposition that it was of value. As it was decided not to be of meteoric origin, however, it remained unnoticed for twenty-eight years, except that a few gun sights were made from it by some of the curious neighbors. A portion of it was sent to the writer and he at once secured the balance of the mass. For figures see Plate X. The mass measures $34^{cm} \times 35^{cm} \times 29^{cm}$ and at the smaller end is 12^{cm} high. Its weight is 197 lbs., (89·796 kilos). It is similar to the Hainholz, Westphalia, iron* is one of the Syssidères of Daubrée and of the Logronite group of Meunier. Two large crystals of olivine are present, one measuring 10×8^{cm} and another 4×6^{cm}; this part being so much lighter in color than the rest of the mass and so much more easily detached that the larger crystals has been almost entirely picked out to a depth of 5^{cm}. At one corner of the mass there is an inclosure of augite measuring 7×4^{cm}. This

* Pogg. Ann., 1857, vol. c, p. 342.

is gray and granular in structure, and has all the appearance of a common gray pebble inserted in the iron. The surface of the meteorite is deeply pitted and in many spots traces of a black crust are still visble; the pitting measures 1 to 4^{cm} across. On one side a fungoid growth has slightly stained it green. Microscopic sections were made, and in these it was seen that the olivine did not occur in separate crystals, but rather in aggregations of irregularly shaped grains, surrounded by brown ferruginous veins and with banded anorthite grains interspersed



here and there. These aggregations are full of black microlites, glass masses and needle-shaped clear crystals, and are imbedded in the metallic iron without any border of alteration. The boundary line is perfectly sharp, fresh and distinct, in which characteristic it differs from the meteorite from Powder Mill Creek. The olivine appears to be fresh, but is clouded with the brown ferruginous stains abundantly scattered through it and between the grains. The following analyses were kindly furnished me by Mr. J. Edward Whitfield, and were made before its identity with the Newton County, Arkansas, meteorite was suspected. He says:

"The analysis of the metallic portion is as follows:

Fe	89·41
Ni	10·41
Co	·29
P	·16
	100·27

Of the rocky portion I have made an analysis of the whole part, i. e., not separated as soluble and insoluble, but with the metallic part separated.

The analysis is as follows:

SiO_2	45·88
Al_2O_3	7·89
FeO	19·73
CaO	6·02
MgO	17·96
NiS	1·67
FeS	·54
	99·69

"From the nickel and sulphur and iron we have the percentage corresponding to the formula (Ni, Fe) S, for the troilite. Taking the piece as it was received the specific gravity is 4·484. Of the finely ground rocky portion, free from metallic particles as far as possible, I have made quite a number of analyses, to learn the nature of the insoluble mineral, and as far as I can judge it is enstatite only and the soluble part is a lime-iron silicate with considerable Al_2O_3. Of the insoluble in dilute hydrochloric acid the following is the analysis.

SiO_2	52·39	= ·87	
Al_2O_3	7·11		
FeO	14·68	·20	·81
CaO	4·49	·08	
MgO	21·33	·53	
	100·00		

"Ratio of $SiO_2 : R''O = ·87 : 81$ which agrees pretty well with enstatite; but here the MgO is replaced by as much FeO and the presence of Al_2O_3 makes the ratio vary a little from the normal 1 : 1. Deducting all the S as NiS and the Fe to correspond to the remaining S from the soluble part, we have for the percentages of the soluble the following:

SiO_2	26·95
Al_2O_3	17·69
FeO	35·98
CaO	15·98
MgO	3·40
	100·00

"The little MgO here probably comes from the slight solubility of the enstatite."

On looking up the literature on this subject the following facts presented themselves.

Prof. Shepard states,* in reference to the Forsyth, Taney Co., Missouri iron, that his first information regarding it was derived from N. Aubushon of Ironton, who reported that a small specimen of very curiously knitted, malleable ore, of a white color resembling silver had been sent him two or three years before by

* This Journal, II, vol. xxx, 1860, p. 205. He had so little of it, that it does not appear on any catalogue, not even in the Shepard collection at Amherst College, Mass.

a person residing near the locality. He had had an analysis of it made and found it to consist of iron and nickel. Prof. Swallow the State geologist of Missouri found it to be composed of similar constituents. He continues: "The mass evidently belongs to the rather rare group of amygdaloidal meteoric irons, in which like those of Hainholz and Steinbach, the peridotic ingredient preponderates over the nickelic iron. Its specific gravity is 4·46. The iron is remarkable for its whiteness, while the peridot is of a well marked green color and distinctly crystalline. No pyrite is visible in the very small fragments examined. It is reported that two very considerable masses of this meteorite were found buried in the soil upon a hill side, and that they are at present secreted under the belief that they contain silver."

Prof. E. J. Cox says * he was informed by Mrs. Scott of Van Buren, that when in the N.W. part of Crawford County, near Penneyoits, Sulphur Spring, attending a barbecue, on July 4th, 1859, about noon, a shower of small meteorites fell on the roof of a cabin half a mile distant, one of which was sent to Capt. Albert Pike, of Little Rock, Ark.† Although twenty-eight years have elapsed nothing has been heard of any of these pieces, in spite of frequent inquiries.

Dr. J. Lawrence Smith‡ describes a meteorite as coming from Newton Co., Ark., but without giving more exact data, as follows: "The original has not been obtained. The only fragment of it being in the hands of Judge Green was given to Prof. Cox, who has kindly presented it to me. The weight of this fragment is 22½ ounces and was evidently broken off from one corner of the mass, as it presents three of the original surfaces. The specific gravity taken on different pieces varies from 4·5 to 6·1. By mechanical means and the aid of the magnet the following minerals were separated: nickeliferous iron, chrome iron, sulphuret of iron, hornblende, olivine and carbonate of lime."

ANALYSES.

NEWTON CO., ARK., J. LAWRENCE SMITH.

Olivine.		*Hornblende.*		*Iron.*	
Silica	42·02	Silica	52·10	Iron	91·23
Alumina	·46	Alumina	1·02	Nickel	7·21
Prot. iron	12·08	Prot. iron	16·49	Cobalt	·71
Magnesia	47·25	Prot. manganese	1·25	Copper, Phosphorus	tr.
	101·81	Magnesia	29·81		99·15
		Alkalies	·24		
			100·91		

* Geol. Reconnaisance, Arkansas, 1860, p. 308.

† Learning that Capt. Albert Pike, now General Albert Pike, resided in Washington, D. C., a letter was sent him in regard to the meteorite; he replied on Nov. 15th, 1887, as follows: "Sometime before the war, and before 1860, I think, I was at Pennyoits Sulphur Springs, some 25 or more miles from Van Buren, and learned that a meteorite had shortly before fallen near there, and had been found. Afterwards a piece of it was procured for me, which became prize of war. I don't know where the piece that I had is or where the residue of the mass went to."

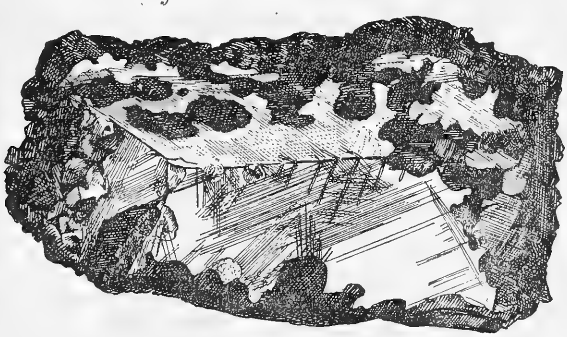
‡ This Journal, xl, pp. 213–216, 1865.

It is very evident that the carbonate of lime which Dr. Smith found in the Newton Co. meteorite was due to an abrasion on the limestone rock, with which the locality where it was last taken, Limestone Valley, is abundantly supplied. Not a trace of this substance could be detected by Mr. Whitfield. The difference in the analyses of the Taney Co. mass will suggest itself at once, but we must consider that these often vary considerable in different parts of the same meteorite?

From all the facts obtained it is quite evident that these two pieces are parts of one and the same meteorite, which originally fell near Miney, in Taney Co., Missouri. It is possible, also, that the report of the fall of a number of meteorites on the 4th of July, 1859, above referred to, may give the time at which this mass fell, although no definite statement can be made to that effect. To Dr. O. W. Huntington and Mr. J. H. Caswell the author is under obligations for comparative and microscopic data, and to Mr. Whitfield for the analysis, and to Prof. F. W. Clarke for his courtesy in regard to the same.

2. *The Chattooga County, Georgia Meteorite.*

This mass of meteoric iron was found by Mr. W. J. Fox, about the 27th of March, 1887, on his farm in Holland's Store,* Chattooga Co., Ga. In all 27 lbs. (12·5 kilos) were found but the mass fell into the hands of parties from Alabama who were interested in developing iron mines, and was broken into pieces, three of which, weighing 9, 1½ and ½ lb. respectively, came into my possession, while the balance were worked into nails, horseshoes and other forms by the local blacksmiths. It is one of the Hexaëdrische Eisen of Brezina, with twinning laminæ, No. 60, and one of the Caillite group of Meunier. The specific gravity as obtained by me is 7·615.



The smaller of the Whitfield Co. masses was found 20 miles N.E., and the larger mass 14 miles N.E. of Dalton, while this was found 30 miles S.W. of Dalton, (see map.) The fracture

* Latitude 34° 22′ North, longtitude 85° 26′ West of Greenwich.

is in part very granular, resembling in this respect the Seeläsgen iron.* But the cleavage is in some parts very marked, and the two cleavage angles measured were 120°. In breaking up the iron four cleavage planes were obtained, one of the surfaces being 2^{cm} square and two others 3^{cm} square each, which were very smooth and bright. On etching with weak nitric acid the iron turned dark and markings became visible that had all the appearance of scratches due to imperfect polishing. In fact they were at first mistaken for scratches and the iron was twice repolished. In this respect, and in its hardness, it very closely resembles the Butcher irons.† They are the Neumann figures, the result of a twinning of the cube described by Tschermak.‡ The iron was then treated with strong nitric acid and evenly dissolved away, with the exception of the (see figure) eating out of one of the layers parallel with the cleavage face and undoubtedly the same with it. It has included round masses of troilite distributed quite plentifully through it, from 3 to 8^{mm} in diameter, and on polishing down the side of the iron these were found so much altered as to be scarcely distinguished as such, rather resembling compact limonite. Lawrencite, chloride of iron, is very plentiful in this iron and collected in large drops on the surface and rolled off into the tray containing the specimen.

The following analyses were kindly furnished by Mr. J. Edward Whitfield, of the U. S. Geological Survey.

	1	2	3	
Fe	94·67	94·66	94·60	
Ni			4·97	
Co			·21	
P			·21	(·207)
			99.99	

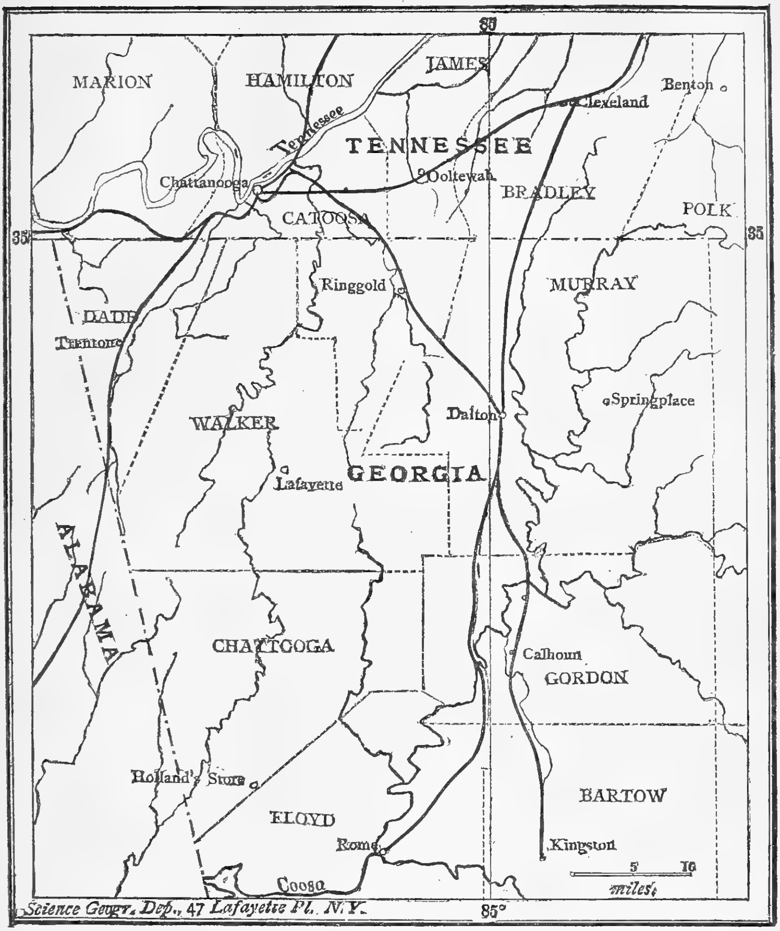
The specific gravity of the largest piece received is 7·801.

There is a very slight trace of S and C but hardly enough to determine.

This iron does not bear the slightest resemblance to either of the Whitfield County, Georgia, irons,§ and is a white iron, whereas the Walker County, Alabama, iron ‖ has a bluish cast and was found over 100 miles due east.

The writer desires to extend his thanks to Mr. Whitfield for the analyses and to Prof. F. W. Clarke for his courtesy.

* Pogg. Ann., 1848, vol. lxxiii, p. 329.
† This Journal, 1869, II, xlvii, p. 383 (see figure).
‡ Akad. Wiss., Wien, lxx, i, page 449.
§ This Journal, III, xxi, p. 286, 1881; III, xxvi, p. 337, 1883.
‖ Ibid., I, xlix, p. 344.



3. *Is the East Tennessee Meteorite from Whitfield Co., Georgia?*

While looking over the literature on the Chattooga Co. meteorite the writer happened upon some facts which seem to give the locality of a very interesting mass of meteoric iron, i. e., that of East Tennessee. Of the original locality we know little definitely. Dr. F. A. Genth says* in regard to an undescribed meteoric iron from East Tennessee:

"Under the date of May 11, 1878, the late Julius E. Raht, of Cleveland, Tenn., wrote me as follows:—I send you to-day a small piece of meteoric iron which was broken from a mass weigh-

* Proc. Acad. Nat. Sci. Philad., 1886, p. 366.

ing 50 lbs., which fell about 8 years* ago near the state line of Georgia, 10 miles† from here (Cleveland). * * * *

The Museum Record of the Academy simply notes the date of its reception as Oct. 24th, 1876, that it came from the mountains of East Tennessee, and weighed 254 lbs. All my efforts to obtain fuller information about its fall and discovery have proved unsuccessful."

Prof. C. U. Shepard, in his description‡ of the meteoric iron of Whitfield County, Ga., makes the following statement:

"Some time during the autumn of 1860, Mr. H. C. Hamilton, of Dalton, Ga., noticed an unusual atmospheric phenomenon in that region. A bright light shot across the heavens, followed by a loud report, which created great alarm among the people, many of whom supposed the end of the world had arrived. * * * A *large mass of iron* supposed to be a meteorite was found about ½ mile from this one in the year 1862 (the 117 lb. Whitfield mass). It was sent to Cleveland, Tenn., where it appears to have been lost sight of."

The following are analyses of the two irons, No. 1 is that given by Dr. Genth, and No. 2 that of Prof. C. U. Shepard, Jr.:

	1. East Tennessee. Sp. grav. 7·521.	2. Whitfield Co., Ga. Sp. grav. 7·986.
Iron	89·93	94·66
Copper	0·06	
Nickel	8·06	4·80
Cobalt	0·56	0·34
Phosphorus	0·66	
Sulphur	not det.	P, Mn, Cr, traces
	99·27	99·80

These analyses do not agree as closely as might be expected, but in some other respects the points of resemblance are close.

A large etched section of the East Tennessee iron in the possession of the writer shows several cracks completely filled with rust, indicating, as Prof. Genth says he had observed, that there are large quantities of chloride of iron in the mass. The large mass of Whitfield Co., deposited in the National Museum, rusts, cracks and exfoliates exactly like the above. The Widmanstätten figures are also identical. A new analysis of the Whitfield Co. mass would perhaps serve to establish their identity.

Cleveland, Tenn., is 28 miles N.E. of Dalton, Ga., and the Whitfield Co. iron was found 14 miles N.E. of Dalton, the latter place being very near the state line (see map). Mr. Raht

* This corresponds with the time given by Mr. Hamilton, of Dalton.

† Given by Prof. Shepard.

‡ This Journal, xxvi, 336, 1883.

also writes that a 50 lb. (?) mass fell* 10 miles from Cleveland near the state line, which locates it very near where the Whitfield Co. mass was found. Cleveland, Tenn., the place from which the East Tennessee mass is said to have been sent, is on or near a railroad line. The mass was probably sent there for sale or to be worked at one of the iron furnaces.

When we consider that the war was then in progress and that even for some years after the war the intercourse which had been broken off was not resumed, it is not unreasonable to suppose that this mass may have lain unnoticed for several years.

4. *On a mass of Meteoric iron from Waldron Ridge, Claiborne Co., Tenn.*

During March, 1887, Judge Fulkerson of Tazewell, Claiborne Co., Tenn.,† received, from some prospector in the vicinity, specimens of what was supposed to be an ore of iron. Some of these were sent to Dr. J. M. Harbison and Prof. W. E. Moses, of Knoxville, Tenn., to Dr. J. S. Newberry, of the School of Mines, Prof. Safford, of the University of Tenn., and others. Through the kindness of the three former gentlemen specimens have come into my possession. This iron is one of the Caillite group of Meunier. In structure it is one of the octahedral irons. On the largest piece, weighing 15 lbs., this is very marked, as it is scarcely altered. All the other pieces, weighing collectively several pounds, have been detached from around this piece, which was apparently the center of the mass. The smaller pieces all show considerable weathering. Several perfect octahedrons and one tetrahedron were obtained by simply breaking the iron off with the fingers, it separating very readily at the cleavage plates between which, in nearly all instances, were thin folia of schreibersite. Troilite was also observed as well as graphite, clearly suggesting that this iron is identical with the Cosby Creek,‡ Cocke Co.,§ the Sevier Co.,‖ the Greenbrier Co.¶ mass in the British Museum, and the Jennies Creek, Wayne Co., W. Va.,** meteorites, which, although independently described, are evidently parts of one meteorite, as suggested by Huntington,†† which either exploded on entering our atmosphere so that the fragments traveled according to their impetus, or else threw off these

* The masses having been supposed to be of meteoric origin it may have been rumored that they had recently *fallen* when they had simply been *found*, and 250 pounds may have been meant instead of 50.

† Latitude 36° 46′ North; longitude 83° 35′ W. of Greenwich.

‡ Troost, this Journal, I, xxxviii, 253.

§ Shepard, ib., I, xliii, 354.

‖ Ib., VI, iv, 83.

¶ Huntington, in British Museum Collection.

** Kunz, ib., III, xxxi, 145.

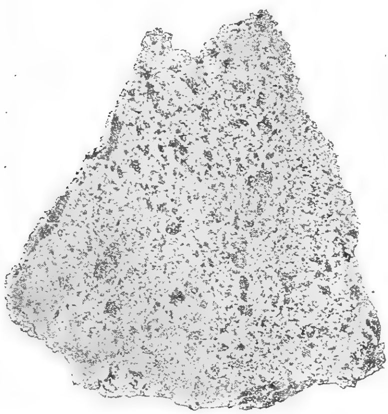
†† Ib., III, xxxiii.

pieces at various periods in its course. In all there was perhaps about 3 pounds, although it was supposed at first that there was a whole mine of it. The other pieces were obtained after the 15 lb. piece, and not one of them weighed more than a pound.

5. *On the Powder Mill Creek Meteorite.**

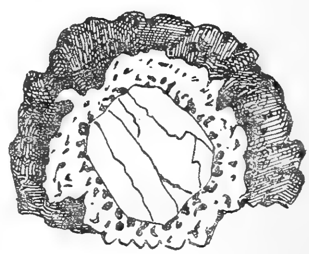
Through the kindness of Mr. Moritz Fischer, of the Kentucky Geological Survey, I am now the possessor of a piece, weighing over 2,000 grams, of the meteorite which Colonel Sublet and Mr. Lenoir found on the farm of Elihu Humber, at Powder Mill Creek, about eight miles west of Rockwood Furnace, on the eastern slope of Crab Orchard Mt., latitude 35° 50′ north, longitude 84° 45′ west of Greenwich, in Cumberland Co., Tenn. (Rockwood being in Roane Co.). It resembles very closely the Hainholz, Westphalia, 1856, and the Newton Co., Arkansas, irons, now the Taney Co., Mo. (see p. 470). It is scarcely distinguishable from the latter (see fig. 1), except that in the latter the grains are larger and more readily defined. The specific gravity was found to be 4·745.

1.



Polished section, natural size.

2.



Magnified 20 diameters.

Chloride of iron (lawrencite) is present in considerable quantities, and on a number of sections which had been cut and polished it was perceptible within a short time. It collected in small beads on the piece itself, which will undoubtedly lead to

* This meteorite is identical with the one described as the *Rockwood meteorite* in the last number of this Journal, and only facts additional to those already published in Mr. Whitfield's article are here given. A part of this meteorite was exhibited and described by the author at a regular meeting of the New York Academy of Sciences, May 30, 1887. The name Powder Mill Creek was given to it because it fell in Cumberland Co.; Roane Co., in which Rockwood is situated, being adjacent to this.

a rapid disintegration unless the iron is coated with varnish or some other preservative. Even small fragments have already become seamed, suggesting that the fall is recent. "Microscopic sections were prepared, and in the ground-mass of metallic iron were seen clear crystals of anorthite and olivine. The former are transparent, with inclusions of glass having fixed gas bubbles, and of many needle-shaped microlites, and some of larger size. The former microlites are probably enstatite, while some black quadratic sections may be chromite or magnetite. The twinning bands of the anorthite are sharp and distinct. The olivine crystals have greenish, brownish veins of alteration (perhaps induced by the lawrencite) with inclusions of glass, microlites and an abundance of black grains of picotite (see figure 2). These grains are occasionally arranged symmetrically around the crystals as a border, outside of which is usually a grayish, partly opaque mass between the crystal and the metallic iron. This grayish mass is an alteration of the olivine which in many cases has taken place in the entire crystal and in others leaving only a small center of clear olivine."

To Mr. J. H. Caswell the writer is indebted for the above microscopical data and to Mr. Moritz Fischer for information and assistance in procuring the pieces of the meteorite.

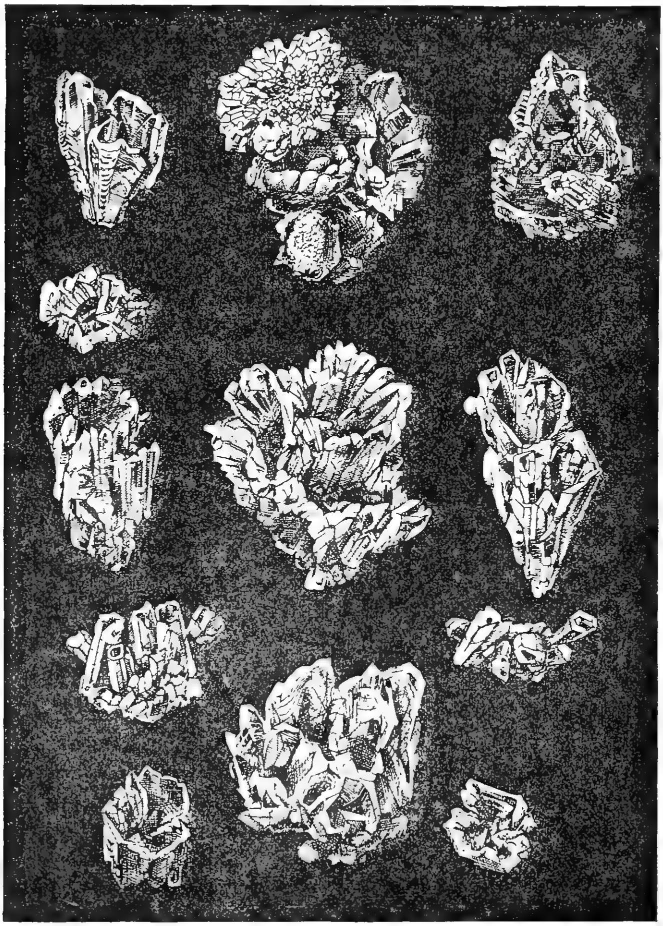
ART. LIV.—*Mineralogical Notes*; by GEORGE F. KUNZ.

1. *Rhodochrosite from Colorado.*

RHODOCHROSITE in rich red, transparent crystals has been found in the John Reed mine at Alicante, Lake Co., Colorado. One specimen shows forty crystals lining a cavity 8^{cm} in width; these crystals are simple rhombohedrons (R), 12^{mm} across, a number of them being entirely transparent. Some cleavage pieces are as pellucid as red Iceland spar and show the same strong double refraction. One of them measured 10^{mm} by 20^{mm} and weighed 2 grams. This is the first locality that has yielded crystals of such magnitude and transparency. The specific gravity is 3·69 and the hardness 3·5; it is not scratched by calcite but is by Bilin aragonite. An analysis, by Mr. James B. Mackintosh, yielded the following results:

MnO	58·325
FeO	3·615
CaO	none
MgO	trace
CO^2 by difference	38·06
	100·00

It also occurs opaque, massive and cleavable, enclosing bright cubic crystals of pyrite at times 25^{mm} across. Some of the crystals are opaque while others are of a transparent flesh color. At the Ulé mine, Lake City, Col., crystals, both opaque and flesh-colored, rounded and curved like dolomite, are found on an argentiferous galena. Some crystals were observed 23^{mm} across. The faces are not polished but rough like the *himbeerspath.* With the spectroscope there is considerable absorption of the citron, forming a decided dark band between the yellow and the green. With the dichroscope the ordinary image is a salmon-pink and the extraordinary light yellow sherry color.



Crystals of Hollow Quartz.

2. *Crystals of Hollow Quartz from Arizona.*

These crystals are found about 3 miles southwest of the town of Pinal, in Pinal Co., Arizona. They occur in a sandstone which has been traced for about one mile; it is penetrated in many places by spherules of obsidian $\frac{1}{8}$ to 3 inches across, which cover the ground like a shower of large hailstones. These quartz crystals are of exceptional interest from the fact that they are mere walls surrounding hollow spaces much larger than the area of the wall itself (see figures on adjoining cut). In some instances the crystals radiate from a central point; numbers of the detached crystals show this very strikingly. At the point of attachment there often appear small nuclei of chalcedony, and in some instances, the crystals radiate from this chalcedonic center so as to form true quartz flowers, as shown in the second figure. Quite often they are single individuals hollowed out, leaving only the smallest edges of what ought to be a pyramid, and the interior of the crystal being hollow to the base in a few instances. They are not cavernous like the Poretta, Italy, and Burke Co. quartz. As hollow quartz their characteristics are sufficiently marked to isolate them from those found at any other locality.

It is very evident that they are the result of a crystallization from a solution, and the chalcedony being rounded and coated white, has every appearance of stalagmitic growth, fading imperceptibly into quartz. In some few instances the quartz crystals have a coating of chalcedony at their terminations. The sides of the prismatic faces are striated and have all the unevenness of those made up of crystalline plates. The hollow crystals themselves are usually made up of six flat individuals so symmetrically arranged as to leave the center hollow, the whole often being one distinct crystal. Many of the crystals are terminated with the pyramid face R only; -1, when present, is usually very small and only slightly developed. Some, however, have both R and -1. In general appearance they resemble the amethyst of Schemnitz, Hungary. The figures were all carefully drawn and are of the natural size.

In this connection it may be mentioned that from near Crouch's Mill, Gaultney's township, Alexander Co., North Carolina, the writer obtained a beautiful group of quartz radiating from one of these chalcedonic nuclei and forming a complete flower that measured 7^{cm} across. None of these crystals, however, were hollow.

3. *Hydrophane from Colorado.*

A white opaque variety of hydrophane, in rounded lumps, from 5^{mm} to 25^{mm} in diameter, with a white, chalky or glazed coating somewhat resembling the cacholong from Washington

Co., Georgia, has recently been brought from some Colorado locality. For its power of absorbing liquid it is quite remarkable. When water is allowed to slowly drop on it, it first becomes very white and chalky, and then gradually, perfectly transparent. This property is developed so strikingly that the finder has proposed the name "Magic Stone" for it, and has suggested its use in rings, lockets, charms, etc., to conceal photographs, hair or other objects which the wearer wishes to reveal only when his caprice dictates. The specific gravity of several specimens was taken with the following results:—Nos. 1–3 were slabs 2^{mm} thick, No. 4 was a natural lump with glazed coating.

	Dry. Grams.	Wet. Grams.	Water abs.	Weight(in water).	Spec. grav.
1.	·880	1·342	·588	·463	2·110
2.	·644	·934	·416	·3385	2·091
3.	·730	1·109	·379	·382	2·097
4.	1·8745		1·0595	·864	2·191

The weight was taken both dry and wet, and it will readily be seen that this hydrophane absorbs more than an equal volume of water.

A remarkable nugget of Silver.

Gen. A. G. Greenwood recently called my attention to a nugget of native silver weighing 606½ ozs. Troy, one of sixty that have been found at the Greenwood group of mines in the state of Michoacan, Mexico. The other nuggets weighed from one to thirty-five pounds each. The large nugget is entirely worn except in cavities where some of the crystals are rounded and the form is still visible. It is almost pure silver, scarcely a trace of any gangue rock being discernible. This specimen was found on the surface, and in its original state is said to have weighed 12 lbs. more. It is one of the most remarkable nuggets of silver ever found. The geological formation is a limestone with outcroppings of limonite.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Study of Chemical reactions by means of the Electrometer.*—Bouty has sought to make use of the electric resistance of solutions in order to determine the chemical changes produced when two dissolved salts are mixed together. Thus, for example, when potassium sulphate and sulphuric acid are mixed in solution, the observed resistance is greater than that calculated on the supposition that no action takes place between them. Hence it follows that the normal salt combines with the acid to

form hydrogen-potassium sulphate. Moreover, as the solution becomes more dilute the quantity of this acid salt diminishes until ultimately it is completely converted into the normal salt. The molecular resistance of the hydrogen-potassium sulphate, which varies according to the same law as that of other salts, is proportional to a factor $1+Km^{\frac{1}{3}}$; the proportion of this acid salt in the solution being given by the expression $y=Ym^{\frac{1}{3}}$. The somewhat high value of $m^{\frac{1}{3}}$ in the formula for the molecular resistance, indicates the dissociation of the acid salt. If the molecule of hydrogen-potassium sulphate constitute a single electrolytic molecule, its resistance at the limit will be that of the normal salt, and in solutions containing not more than one-tenth of a gram-equivalent per liter the difference between the resistances of the two salts will be a vanishing quantity compared with the much greater conductivity of the free acid. It is found that the proportion of the acid sulphate, calculated from the observed resistances of the liquid, increases with the temperature. Hence, combining this with the previous result, it follows that hydrogen-potassium sulphate is more stable in warm and concentrated solutions. At the same temperature and with the same degree of concentration, the proportion of the acid salt increases with an increase in the relative proportions of either the free acid or the normal salt, an excess of the normal salt being more favorable to this change than an excess of sulphuric acid. These results agree with the results of Berthelot's thermo-chemical investigations. Possibly the great variations in the resistance of abnormal salts and of free acids may be due to a progressive dissociation of complex electrolytic molecules, according to the same law as that of hydrogen-potassium sulphate; but this effect, while added to, will not modify the law of the variation of the resistance of salts which are normal in all degrees of dilution.—*C. R.*, civ, 1789, 1839; *J. Chem. Soc.*, lii, 882, October, 1887. G. F. B.

2. *On the Detection of minute traces of Carbon dioxide.*—In order to detect minute traces of carbon dioxide Rössler has modified the ordinary method as follows: The lower end of a test tube is drawn out to a narrow tube which is then turned upward and to one side, the opening being about a centimeter above the bend. A piece of thin glass tube, rather larger in diameter than the test tube, is drawn out to a gradual taper so that while at top it rests upon the test tube, its lower and capillary end is from 1·5 to 2^{cm} from the bottom of the this tube. The substance to be examined is placed in the bend of the test tube. The capillary funnel is then partly filled with baryta water so as to leave a drop hanging from the lower end, and is placed in the test tube. Upon dipping the apparatus in hydrogen chloride, the acid enters the capillary opening of the test tube and comes in contact with the substance in the bend. The evolved carbon dioxide comes in contact with the baryta water and produces the well known turbidity. To test the delicacy of the apparatus, sodium carbonate was mixed with sodium chloride and introduced into it. When the former was 0·005 gram the turbidity was strong. With 0·0005,

it was very distinct; and with 0·00005 gram, it could be seen on close observation. This corresponds to 0·02 milligram carbon dioxide. By placing starch and potassium iodide in the capillary funnel, sulphurous oxide is easily detected in this way. Concentrated ferrous sulphate may thus be used to detect nitric acid vapors, a mixture of nitrate and common salt being used with sulphuric acid. Hydrogen sulphide is thus detectible by lead acetate, ammonia by copper sulphate, nitrous acid by potassium iodide, etc.—*Ber. Berl. Chem. Ges.*, xx, 2629, October, 1887. G. F. B.

3. *On the Heat of Combination of Tellurium.*—BERTHELOT and FABRE have determined the heat of combination of several different varieties of tellurium by pulverizing them finely, dissolving them either in bromine or in water saturated with bromine, and measuring the thermal disturbance thereby produced. Crystallized tellurium, prepared by volatilization in hydrogen evolved 66·66 calories. Tellurium precipitated by sulphurous acid 42·584 calories; precipitated from alkali tellurides by the action of the air or other oxidizing agents, 66·78; precipitated from hydrogen telluride by oxidizing agents, 67·01. The last two varieties are identical with the first, therefore; and hence, taking the mean of the three at 66·776 calories, it follows that the conversion of crystallized tellurium into the amorphous variety develops 24·192 calories. Consequently tellurium, like sulphur and selenium, exists in two perfectly distinct states. Molten tellurium, thrown into cold water and then treated as above, gives numbers varying from 44 to 56 calories, indicating that it is a mixture of the crystalline and amorphous varieties. It is rather a curious fact that while the change from amorphous to crystalline tellurium absorbs heat, the corresponding change for selenium evolves heat, and the change in the case of sulphur gives rise to no sensible thermal disturbance at the ordinary temperature; though at a high temperature it is positive and is probably negative at a low one.—*C. R.*, civ, 1405–1408; *J. Chem. Soc.*, lii, 761, September, 1887. G. F. B.

4. *On the occurrence of Aluminum in the Ashes of Flowering Plants.*—It has long been the current opinion of chemists that aluminum is not a normal constituent of flowering plants, the occurrence of this element in the ash of phanerogams being generally attributed to adhering particles of the soil. YOSHIDA has undertaken a set of careful analyses of several seeds and grains with a view to decide the matter, and he finds in the hull or skin of a pea (*Soja hispida*) 0·268 per cent of alumina, in the red bean (*Phaseolus radiatus*) 0·096, in rice (*Poddy*) 0·189, in wheat 0·106, in barley 0·140, in millet (*Panicum italicum*) 0·272, and in buckwheat, 0·113 per cent. The cotyledons of the pea alone of all the substances analyzed contained no alumina.—*J. Chem. Soc.*, li, 748, October, 1887. G. F. B.

5. *On Ammonio-cobaltic permanganates.*—KLOBB has described a series of new salts, which are exceedingly beautiful and at the same time highly explosive, and which are obtained by

adding cold solutions of potassium permanganates to ammoniacal solutions of metallic salts. With silver nitrate the compound $(NH_3)_2AgMnO_4$ is obtained as a dark violet crystalline powder which detonates on warming. Similar salts are given with copper, cadmium, nickel and zinc. The most interesting, however, are the salts of the ammonio-cobalt bases, particularly luteocobalt. Its permanganate is obtained by mixing concentrated solutions of luteocobalt chloride $(NH_3)_{12}Co_2Cl_6$ and potassium permanganate at a temperature not above 60°, in the proportion of one molecule of the former to twelve of the latter. The new salt separates on cooling in little black quadratic octahedrons having a brilliant luster. If powdered and carefully warmed in a test tube these crystals decompose suddenly with incandescence, but if heated without pulverization, they incandesce with detonation, the tube being shattered into fragments. When struck with a hammer, the crystals detonate violently; even powdering them in a mortar being sometimes accompanied by dangerous crepitations. This salt has the formula $(NH_3)_{12}Co_2(MnO_4)_6$. Other compounds have been obtained in which hydrogen chloride and hydrogen bromide partially replace the hydrogen permanganate. A beautiful salt of this kind has the composition $(NH_3)_{12}Co_2(MnO_4)_4Cl_2 . (KCl)_2$. It forms dark violet hexagonal plates bearing often low six-sided pyramids, and sometimes grouped together in the form of six-rayed stars resembling snow flakes in shape. These salts are less explosive than the others.—*Ann. Chim. Phys.*, VI, xii, 5–33, September, 1887. G. F. G.

6. *On the Character of Solution.*—MENDELÉJEFF has given a definition of solution and has illustrated his views in the particular case of solutions of ethyl alcohol in water, the data being here very accurate. "Solutions" he says "may be regarded as strictly definite atomic chemical combinations, at temperatures higher than their dissociation temperature." Just as definite chemical substances may be formed or decomposed at temperatures higher than those at which dissociation commences, so in solutions; they can be either formed or decomposed at ordinary temperatures. Moreover, the equilibrium between the quantity of the definite compound and of its products of dissociation is defined by the laws of chemical equilibrium, which laws require a relation between equal volumes and their dependence on the mass of the active component parts. If, therefore, the above hypothesis of solution be correct, comparisons must be made of equal volumes, and the specific gravities are the weights of equal volumes. Moreover, we must expect the specific gravities of solutions to depend on the extent to which the active substances are produced. Hence the expression for specific gravity s, as a function of the percentage composition p, must be a parabola of the second order: $s = N\ (p \pm a)\ (100 - p \mp a)$

This may be represented by the general equation

$$s = C + Ap + Bp^2$$

Between two definite compounds which exist in solutions, it is to be expected that the differential coefficient $\frac{ds}{dp}$ will be a rectilinear function of p: i. e., $\frac{ds}{dp} = A + 2Bp$. This conclusion can be verified by experiment. Moreover, it gives the means of ascertaining what the definite compounds are which exist in the solution. Applying now the method to the solutions of H_2O and C_2H_6O, three definite compounds are found to exist: C_2H_6O with $(H_2O)_{12}$ and $(H_2O)_3$, and (H_2O) with $(C_2H_6O)_3$; containing 17·56, 46·00 and 88·46 per cent of alcohol respectively. The rectilinear character of the differential coefficient is shown by plotting the results in a diagram. Calculating the constants of the parabolas, expressions are obtained for the specific gravity in terms of the percentage composition, the values calculated from which agree very closely with those obtained by experiment. The author finds tho above hypothesis respecting the rectilinear character of the differential coefficient to be correct, not only for solutions of a hundred different salts but also for solutions of H_2SO_4, of NH_3, of HCl, and other similar substances. Indeed up to the present time he has not met with a single solution which is an exception. At present he is investigating minutely, solutions at low temperatures; and in connection with Teeshenko he has already obtained the compounds $C_2H_6O(H_2O)_{12}$ and $C_2H_6O(H_2O)_3$ in the solid form and crystallized; the former at $-17°$ C., and the latter in a mixture of solid CO_2 and ether.—*J. Chem. Soc.*, li, 778–782, October, 1887. G. F. B.

7. *On the Chemical action of Bacterium Aceti.*—Brown has continued his experiments on the chemical action of the ferment *Bacterium aceti.* He had shown that mannitol is completely decomposed by it, levulose being the main product. He now finds that its isomeride dulcitol suffers no change whatever by the action of the ferment. Glycol is readily oxidized to glycollic acid. Glycerol is converted into carbon dioxide and water. Erythrol undergoes no change whatever. Hence, by transforming dextrose into mannitol by sodium amalgam, and mannitol into levulose by the ferment, dextrose may be converted into levulose. Moreover, Brown finds that the cellulose formed by the ferment *Bacterium xylinum* from levulose, yields a dextrorotatory sugar on treatment with sulphuric acid.—*J. Chem. Soc.*, li, 638, July, 1887. G. F. B.

8. *On the light emitted by glowing solid bodies.*—According to Dr. J. Draper, all solid bodies begin to glow at the same temperature, which is about 525° C. As soon as a platinum wire, heated by an electrical current, reaches a temperature slightly above 525°, the light emitted shows a spectrum from the line B to *b*. When the temperature reaches 645°, the spectrum extends from B nearly to F. At the temperature 718°, it extends from B to G. And at the temperature 1165°, the spectrum has nearly the full extent of the solar spectrum. Dr. Draper was led

to believe that the increase in the spectrum was toward the more refrangible end. H. F. Weber, from observations on incandescent electric lights, has discovered that bodies begin to glow at a much lower temperature than the limit set by Draper.

The first trace of light was seen at about 390°, and was of a spectral gray color. As the temperature increased, the spectrum of the glowing carbon filament did not increase more rapidly toward the violet than toward the red; but increased equally in both directions. The first rays which are perceived by the eye come from the part of the spectrum which sends forth the maximum energy when the filament is heated to its highest point. The experiments were repeated with metallic filaments raised in temperature by non-electrical methods, and the results obtained by electrical currents were thus confirmed. Weber maintains also that all bodies do not begin to glow at the same temperature, as the results of Dr. Draper seemed to show. A plate of platinum began to send forth gray light at 391°; while a gold plate showed the same character of light at 417°. In another experiment, a platinum plate began to glow at 396°, and an iron plate at 378°. The paper of Weber is followed in the *Annalen der Physik* by one on the same subject by Fr. Stenger, who confirms in general the results of Weber; but suggests that the varying sensitiveness of the observer's eye to various colors and to their degrees of intensity may play an important rôle in the determination of the relative rate of increase of the spectrum of glowing bodies.—*Ann. der Physik und Chemie*, No. 10, 1887, pp. 256–275. J. T.

II. Geology and Mineralogy.

1. *On the Location of some Vertebrate Fossil Beds in Honduras, C. A.;* by Frank L. Nason.—The locality referred to is situated about twenty-seven miles east of the Ulna river and in the Nigrito valley. This valley is bounded on the east and west by ranges of lofty mountains varying in height from three to six thousand feet. The mountains gradually draw together north and south, enclosing a basin from forty to fifty miles in length and about twelve in width. From the northern extremity of the valley two streams (one of them the Rio Roman), join to form the Rio Comayagua, which empties, later, into the Ulna, thus forming the outlet or drainage for the valley.

At the foot of the mountains are ranges of foot-hills not over one thousand feet in height. These foot-hills are evidently the débris washed from the mountains and into the lake which at that time filled the valley. A rather striking feature of these foot-hills, as well as of the valley, is the almost entire absence of tropical vegetation. While the mountains are clothed with the customary tangled growth, these hills and the valley have only straggling thickets of guava and other shrubs, though quite a dense growth of grass is abundant which furnishes pasturage

for large herds of cattle. The nature of the soil is the only sufficient explanation of this change of vegetation.

The soil is a very tough clay filled with weathered bowlders of all sizes. An examination of the bowlders showed them to consist largely of a coarse-grained diorite from the decomposition of which the clay is formed. Aside from the numerous pyramid-shaped piles of stones scattered around, examinations were made in the beds of gullies with perpendicular walls, cut by the water during the rainy season.

It was while examining the stones in one of these gullies, that my attention was attracted by several huge bones projecting from the walls. My interest was at once awakened on account of this being a possible intermediate link between the great Tertiary Lake formations in the United States and Mexico, and those in the U. S. of Columbia. I had only my geologist's hammers with me, and with these no headway could be made in extricating these bones from the tough clay. Had I succeeded in extracting them no means were at hand for carrying them to the coast twenty miles away.

Upon inquiry of our host, through our interpreter, he informed me that the entire skeleton of a huge animal had been washed from the soil a few years before, but that all but a few fragments had been destroyed by the inhabitants who were more curious than scientific. A few fragments were shown me, and as there were bits of much decomposed ivory among them, I concluded that the remains were those of Mastodons or other allied species.

I was further informed that a very perfect skeleton had been taken by the government to the college at Santa Barbara. Business prevented my visiting this town and I am unable to confirm the report. There is great likelihood that this locality is very rich in vertebrate remains, and that search for them would be comparatively easy on account of the natural sections cut by the streams which are dry except during the rainy season.

Nor would the paleontologist alone find working material. The foot-hills, to which I have alluded, bear numerous traces of former inhabitants, as well as demonstrate that the valley was formerly a lake. On the summit of these hills are very frequently found great heaps of bivalve shells about the form and size of the ordinary fresh-water clam. They could not have been taken from the modern streams as they are all rapid, and I noticed only such univalves as are commonly found in such places. Among these shell heaps are frequently found flint and stone implements, and also bones and the rude stone images often found among the Aztec ruins. These last two statements I am unable to vouch for as my limited time allowed only a hurried search.

It may be interesting to note that, to me, the Nigrito appears to be but one of a chain of lakes which extended from the Ulna river to near the river Poyas, about two hundred miles east.

There is no doubt but that a scientific party, with leisure, would be richly repaid for time spent in exploring this section of

country, less known, perhaps, than any other country in Central America. Abundance of vertebrate fossils, and relics of past human races as well as plain though fast vanishing marks of the early explorers of this country, fill these valleys from the Ulna river to Truxillo.—*Communicated to this Journal by the author.*

2. *Professor L. F. Ward's Synopsis of the Flora of the Laramie group.*—The following notes on Professor Ward's valuable work are from a letter of August 9, 1887, to the author from Mr. L. Lesquereux, received from the former by the editors.

I am delighted with your excellent exposition, and thank you heartily for the pleasure and instruction I have received from it. Of course I do not agree with you in all your views, nor even with all your assertions; though that proves nothing against you. I will only mark a few of the points on which I do not fully agree with you.

Considering the climatic circumstances, as indicated by the local presence of some species of plants, you say, p. 438, that the Palms of the lower districts of the Laramie indicate a difference of climate greater than can be accounted for by the small difference of latitude. From Dr. Newberry's "Later Extinct Floras" and from Dr. F. V. Hayden's remarks, it appears that the largest specimens of fossil Palms (*Sabal Campbellii*), have been found in the Fort Union Group; near the mouth of the Yellowstone, I suppose. From the Raton Mountains, where plants of the same kind are found in abundance, there is a difference of 22° of latitude; and in that distance there is no marked difference in the characters of the vegetation of the Laramie group, not even in the absence of Ficus or of Cinnamomum at certain localities, and therefore only a mere local difference. *Cinnamomum affine* Lx., a close relative of *C. polymorphum*, is not rare in the higher strata of the Laramie, where you place the locality of Carbon. Your exposition of the flora of the Iron Bluff, so remarkably varied and different in each of the successive strata, is the best possible indication of the extraordinary variety of the groups of floras of the Laramie, though separated they may be at the same localities by their intermediate strata. The same difference is remarked at Golden where, apparently at nearly the same horizon and at little local distance, one of the strata bearing vegetable remains has, in abundance, leaves of Platanus, *Ficus Goldiana*, and *Ficus spectabilis*, while the other has mostly leaves of some species of Populus and none at all of the species of the first examined bed. This, it seems, shows the impossibility of considering the difference in the vegetation of the Laramie at different localities as influenced by mere climatic circumstances.

In the arrangement of your table of distribution which has been prepared with the greatest care and has certainly demanded long and careful research, I have to remark only on the admission of the Credneria beds of the Upper Quader into the Senonian. They are placed by Hosius at the very base of the Senonian, from which he has a few leaves of Credneria. But the type of these leaves is older; it pertains to the lower Quader or the Cenoman-

ian, and for many geologists most of what is considered Upper Quader is of the same age as the Lower. In any case, if even your splendid leaves, which you refer with doubt to the genus, were true Credneria, their relation should be indicated as with the Cenomanian or with the original type, not with the derived one in the Senonian. This, however, is of little importance, as really the characters of these leaves are, in my view, far different from those of Credneria, especially on account of the basilar position of the lowest secondaries (or lateral primaries) and the absence of the secondaries, or rather tertiaries, underneath. It is also from the basilar point of attachment of the lateral primaries that I can not recognize the identity of the two leaves of pl. xl, fig. 8 and 9, with *Platanus Heerii*, whose leaves are moreover entire.

There is, however, a species of the Dakota group which shows the closest relation (even identity?) to species of the Laramie. It is *Populus elliptica* Newby., which can scarcely be separated by distinct characters from *P. cuneata* of the same author. This last species is therefore evidently of Cenomanian type, the first being the ancestor of *Populus arctica*, *P. Richardsoni*, *P. Zaddachi*, *P. speciosa*, *P. amblyrhyncha*, *P. Daphnoides*, *P. Oxyrhyncha*, etc. The type is not seen with the Cretaceous of Greenland; not even in the Patoot Senonian. But it is reproduced, and frequently so, in the Tertiary of Greenland, as you well know. This with a number of other affinities tend to show, in my opinion at least, that if there has been a migration of the plants between America and Greenland at the Cenomanian period, the migratory movement has been northward, not southward. But this question is out of place here.

I received last Saturday the No. 37 Bulletin of the Survey with the figures and descriptions of your Types of the Laramie. This small volume is very handy and for study of paleobotany more valuable still than the synopsis. Though I have sent an acknowledgment of receipt to the Survey, I take the liberty to thank you heartily for the production of a book which will be of great assistance to paleobotanists of the present and especially for the future American students of vegetable paleontology. What an immense amount of material is still in reserve for those who follow in your footsteps and collect specimens along the Yellowstone! How is it that you did not find any Palms near Fort Union, or along the Yellowstone?

Very sincerely and thankfully yours, LEO LESQUEREUX.

Professor Ward has sent the editors the following remarks on Mr. Lesquereux's letter.

To certain of the above criticisms, the force and legitimacy of which I freely concede, the following reply may be made.

I was not so fortunate myself as to find Palms in the Fort Union beds, and the only ones coming from them that are known to me are those determined by Dr. Newberry to which Professor Lesquereux refers, and which represent only a single species, *Sabal Campbellii* Newby., which occurs so abundantly at Golden,

Colorado. This species will be found properly entered in the table of distribution on page 467, and the total absence of Palms in the Fort Union group was not maintained. They certainly must have been rare in this section, whereas they are found in nearly all the beds in Colorado and Wyoming. The same disproportion is found in the genus Cinnamomum.

As regards the age of the Credneria beds of Europe I can only say that those of Brankenburg, where Zenker first found the genus, and of Quedlinburg, where a number of species occur, are placed by Schimper (Traité de Paléontologie végétale, vol. iii, p. 673) in the Senonian of D'Orbigny, as are also those of Westphalia, since so much more thoroughly studied by Hosius and Van der Marck, who located them in the lower portion of that member. Most of the other Credneria beds lie in the Lower Quader and should doubtless be correlated with the Cenomanian. Such are those of Silesia, Saxony, Bohemia and Moravia. Schimper, however, would place Moletein, where Heer's *C. macrophylla* was found, in the Turonian (op. cit., vol. iii, p. 59). I do not certainly maintain with any force that my *C. daturæfolia* represents a true Credneria, and I have set forth in my Types of the Laramie Flora (p. 98), which Professor Lesquereux had indeed received but probably had not yet examined on this point, all the objections raised by him to such a reference, together with some others. I merely wished to make a suggestion sufficiently startling to attract attention to this remarkable form and to call out the opinions of others as to its proper affinity.

LESTER F. WARD.

3. *A pot-hole of remarkable size in Archbald, Pa.*—The pot-hole recently brought to light in the coal formation at Archbald, Lackawanna County, Pa., according to an account of it in the Scranton Republican of November 4, 1887, has a depth of forty-five feet, and a somewhat ovoidal section with the largest diameter twenty feet. Its lower end was discovered in 1883 in the process of coal mining, and since then it has been cleared and used as an air-shaft. It is on the property of Mr. E. B. Hackley, who has taken precautions, at considerable expense, to ensure its preservation. It is supposed to be a product of the latter part of the Glacial era, and to have been made by a great water-fall descending through a crevasse in the glacier. This view implies that the glacier of the region did not move on as much as ten feet during the centuries in which the excavation to a depth of forty-five feet was going forward; or else that the local conditions occasioning the crevasse were such as to keep the crevasse stationary, and without eroded sides from the water-fall, during those centuries, notwithstanding the movement of the glacier. Either supposition seems to be almost incredible. The other explanation supposes a great river, made from the melting of the glacier, to have done the excavation by the usual river methods, that is, while flowing in torrents along a shelving, rocky shore.

4. *The Lake Age in Ohio, or some Episodes in the Retreat of the N. American Glacier.*—A paper on this subject by Professor

E. W. Claypole, illustrated by maps, is contained in the Transactions of the Geological Society of Edinburgh, 1887, p. 421.

5. *Carboniferous Fossil Corals.*—Mr. James Thomson has a paper on the genus *Lithostrotion*, its limits, characters, and species. Ibid., p. 371.

6. *Primordial Fossils from Mt. Stephens, N. W. Territory of Canada;* by Dr. C. Rominger.—The species embrace Trilobites of the genera *Ogygia*, *Embolimus*, *Menocephalus ?*, *Conocephalites*, *Bathyurus ?*, and *Agnostus.* The beds contain also species of *Obolella*, *Orthis*, *Kutorgina*, *Theca* or *Hyolites.*—*Proc. Acad. Nat. Sci. Philad.*, 1887, p. 12.

7. *The Teachings of Geography:* suggestions regarding principles and methods for the use of Teachers; by ARCHIBALD GEIKIE, Director General of the Geological Survey of the United Kingdom. 202 pp. 12mo. London and New York, 1887, (Macmillan & Co.)—Dr. Geikie's geological science has enabled him to give special value to this work for instructors in geography.

8. *A North Carolina Diamond.*—Mr. G. F. KUNZ states that a diamond weighing $4\frac{1}{3}$ carats or 873 milligrams was found on the Alfred Bright farm in Dysartville, McDowell County, N. C., in the summer of 1886. It is quite perfect, but not pure white, having a faint grayish-green tint. In form it is a distorted hexoctahedron with partial twinning (see figure of two views). Its specific gravity is 3·549, and it measures ten millimeters in length and seven millimeters in width. A number of small stones exhibited as diamonds have been found at Brackettstown, near by, but they have proved to be either transparent zircon or smoky-colored quartz. A visit to the locality served to authenticate the facts of its discovery. None of the minerals ordinarily associated with the diamond were found at the locality, and the opinion is expressed that the diamond must therefore have been transported from distant higher ground in the vicinity during a heavy freshet.

9. *Herderite.*—The rare mineral herderite, long known only in a few unique specimens from Saxony (1828) and later (1884) found at Stoneham, Me., has been recently obtained from Mursinsk in the Ural. The crystals are associated with yellow orthoclase, smoky quartz, tourmaline, muscovite and topaz; in habit they resemble the original mineral more nearly than that of Stoneham. —*Berwerth. Ann. Mus. Wien*, 1887.

10. *Periclasite.*—The rare oxide of magnesia (MgO), occurring only at Monte Somma, has been identified at the manganese mines of Nordmark in Sweden. Blowpipe trials show the presence of a little manganese and iron.—*Œfv. Ak. Stockholm,* Sept. 14, 1887.

III. BOTANY.

1. *Monographiæ Phanerogamarum Prodromi*, Vol. v. *Pars secunda: Ampelideæ*, auctore J. E. PLANCHON, has at length appeared. It occupies 350 pages; and it represents a great

amount of labor, the permanent value and complete acceptance of which cannot be adjudicated off-hand. The plan of merging all the forms into one genus, *Vitis*, has been abundantly tried, not with very satisfactory results,—partly, it may be, because the groups have not been well worked out. Professor Planchon, a most experienced and keen botanist, who has especially investigated the Vines for a good many years, has very naturally tried the other tack, and has developed the Linnæan *Vitis* and *Cissus* into ten genera. The principles upon which he has proceeded, as explained in the preface, are wholly legitimate; and one could wish that they have been successfully applied. This, only use can determine. We may be confident, however, that if this monograph had been in the hands of the authors of the latest Genera Plantarum, they would not have bodily adopted its conclusions, although they would have been much helped by the elaborate investigations, and might have seen their way to admit three or four genera. They would not have trusted over-much to the difference between polygamo-diœcious, polygamo-monœcious and partly pseudo-hermaphrodite, hermaphrodite and probably some pseudo-hermaphrodite, and hermaphrodite or rather physiologically polygamo-monœcious and with some blossoms pseudo-hermaphrodite,—differences which must be shadowy,—nor to variations in the mere shape of style and stigma. And as to the disk, which should be more tangible and hopeful, we gather from Planchon's synopsis and from our own observations that there are only three types. In the true Grape-vines, the disk is represented by nearly distinct and free nectariferous glands, alternate with the stamens. In most other Ampelideæ, it is cupular or annular (entire or crenate or lobed,) with base or lower half or more adnate to the base of the ovary, but at least the margin or lobes free. In the Virginia Creeper there is really no disk at all, as was first noted by Dr. Torrey in his Flora of the Northern States, in 1824, and insisted on in the Flora of North America, in 1838, and again in the Genera Illustrata, where there are correct figures. Dr. Planchon expresses the same opinion in essence but in different language, i. e., "Discus obsoletus ovarii basi plane adnatus et tantum colore proprio subdistinctus." We could not make much of the color; but the tissue does thicken more or less, and possibly may become obscurely nectariferous; but the flowers are not attractive to bees, as the allied species from Japan is. In the latter while there is equally no *hypogynous* disk, there is much thickening of nectariferous tissue over all the lower part of the ovary more or less in longitudinal ridges, the whole 'plane adnatus' throughout. Now we should make more of these three types than Dr. Planchon does. For the first goes with the Calyptrately Caducous corolla and polygamo-diœcious flowers of true *Vitis*. The third with disk, if so called, wholly confluent with the ovary itself, belongs to and includes all of the few known species (including Planchon's *Landukia*) which have the striking biological character of climbing by the dilatation and adhesion of the tendril tips; and their flowers are 5-merous, essentially hemaphrodite, and

with expanding corolla. The second type of disk goes with 4-merous and some 5-merous flowers with corolla expanding in anthesis, that is, to the genus *Cissus.* We do not see the way to break this up into genera—certainly not on the number of parts, for this varies in some species, and while *C. stans* is 5-merous, the closely related *C. orientalis* is 4-merous. However it may be with some exotic groups, we must restore our two species, which formed part of Michaux's *Ampelopsis,* to the genus *Cissus.* Under that view the generic nomenclature is clear. The genus *Ampelopsis* (Michaux, p.p. and Torr. and Gray) is to be maintained on the lines long ago laid down in this country, and now reinforced, for those species which are popularly well-known under this name. We do not feel obliged to defer to any work of Rafinesque as late as the year 1830. But, as to the present point, it seems to us that when Dr. Planchon followed him in the appropriation of one part of Michaux's *Ampelopsis,* he should also have adopted Rafinesque's name for the other part, viz: *Quinaria,* instead of making a new name, *Parthenocissus,* the former name being free for use. Under our view both names are superfluous. As to true *Vitis,* it remains to be seen whether it will be at all possible to distinguish twenty or more North American species. Perhaps Engelmann allowed quite as many as can be defined. But Planchon's long and conscientious labors upon the genus and the family must be most helpful even where his conclusions are not at once accepted. A. G.

2. *Report on Botanical Work in Minnesota for the year* 1886 occupies Bulletin No. 3 of the Geological and Natural History Survey of that state. There are, first, papers by Professor L. H. Bailey, sketches of the flora of Vermillion Lake and other northern parts of Minnesota, with lists of plants collected. Monotony and paucity of species characterize the flora between Lake Superior and the international boundary; and this is taken "as an illustration of the law that species decrease with the increase of latitude," as if there were no other sufficient explanations of the floral poverty of that tract. Mr. Upham adds a supplement to his list of the flora of Minnesota, adding about two dozen species. The first is the *Anemone nudicaulis* Gray, in Bot. Gazette, reprinting the article, but with no further information. We had hoped that the station would ere this have been revisited. A. G.

3. *The Course of Practical Instruction in Botany,* by Professor Bower and Professor Vines, of which the first part was published in 1885, is now completed on the same lines by the issue of a second part for the Bryophyta and Thallophyta. This part is the work of Dr. Bower, and, of course, it is an excellent manual for the botanical laboratory. It is published by Macmillan & Co., London and New York, pp. 144, 18mo. A. G.

4. *Grasses of North America for Farmers and Students,* etc., W. J. Beal, Professor of Botany and Forestry in Michigan Agricultural College. An octavo volume replete with information, not only about grasses but clovers and such-like forage plants, and many other matters, scientific and practical. It

begins with "protoplasm," it ends with "debris," or bits of wisdom—poetic and prosaic, secular and biblical—left over when the book was done, "for want of a suitable place to use them." There is, last of all, a bibliography, in which *the* Robert Brown is not discriminated from *a* Robert Brown, author of a Manual of Botany, owing, no doubt, to the exceeding brevity of citation; while, by some odd mishap, Bentham and Hooker's Genera Plantarum is said to be published at Berlin. But it is hardly gracious to notice such blemishes, nor to complain of proof-reading and form, since the book was printed at Lansing, yet not badly in most respects. The numerous figures are mainly particularly good, not only those of grasses drawn by Mr. Scribner, but also the microscopic illustrations by Sudworth. The short and good chapter on the Fungi of Forage Plants is contributed by Professor Trelease; and the original figures, if not fine, are fairly effective. Not content with giving, in this volume, a practical account of the principal forage grasses, with their physiology, morphology, cultivation and management,—in which "it is hoped that the farmer or general reader who has never studied botany will find much to interest and help him"—and the hope is amply warranted—the author announces a second volume, to contain the description of all known grasses of North America, 700 or more species. This is a more formidable undertaking, whether the treatment is to be mainly popular and practical, or more scientific, or both combined. A. G.

5. *Serjania Sapindacearum Genus monographice descriptum;* von L. Radlkofer, was published in 1875 in the Transactions of the Royal Bavarian Academy at Munich, and it gained the Candollean quinquennial prize, as well it might. This accomplished systematic botanist has now published, in a later volume of the same series a detailed supplement, of nearly 200 pages and 9 plates, the last a distribution map. Moreover, the *Fish-inebriating Plants* have been taken up by Dr. Radlkofer (Sitzungsberichte der Bayer. Acad. Wiss., xvi, 1886, p. 380) *apropos* in the first instance to two notable species of *Serjania*, treated of in his monograph of that genus. To the present paper is added an *Index plantarum ad pisces capiendos adhibitarum*, arranged under their natural orders. The list amounts to 154 species, besides twenty others which, being known only under popular names, are dubious. A. G.

6. *The British Moss Flora*, its indefatigable author, Dr. Braithwaite, has, in Part x, completed the first volume of. It runs to 315 pages, with 44 plates (such as only Sullivant could rival), all executed by his own hand. This admirable work is published by the author, at 303 Clapham Road, London. We are informed that the sale so far covers the actual outlay, and that it will be continued. Would that we could have such a moss-book, with figures of all our North American species; but as that may not be as yet, and as the species are largely the same, our bryologists should thank Dr. Braithwaite for all he is doing for them. A. G.

7. *Pittonia, a Series of Botanical Papers*, by Edward L.

GREENE, Assistant Professor of Botany in the University of California, part 2, just come to hand, bears the date of July, 1887, and carries on the volume to p. 93. The opening pages explain for the benefit of the uninstructed, the meaning of the convenient catch name *Pittonia*, seemingly with some idea of retrieving an injustice done by "the rising Swedish authority [who] arbitrarily set aside the then old and well established name Pittonia and put his own new and more cumbrous Tournefortia in its place." Well, in his day we know that Linnæus felt very much at liberty in such matters, and wished the genus to bear the real cognomen of the botanist it commemorated. Plumier himself dedicated his genus to Josephus Pitton Tournefort, which is also the name on the title page of the *Institutiones.* On the title pages of the two earlier works it is simply Mr. Pitton Tournefort, and there is no intimations that he ever used the *de.* So we have rather to bless Linnæus for transgressing a rule which did not then exist. In a following article Professor Greene gives an account of a monstrosity of *Collinsia bicolor* having mainly regular corollas, and thereupon suppresses Nuttall's genus *Tonella* at once. Next two new genera are made out of portions of *Krynitzkia*, and *Piptocalyx* is set up anew; a good number of miscellaneous new species are described, and a detailed account of *Carpenteria Californica* is given, quite unaware that this shrub is now rather commonly cultivated in Europe, and has been figured in the Botanical Magazine, The Garden, Gardener's Chronicle, etc. That the parts of the flower, at least the calyx, are sometimes 6 or 7 is stated in the original description, indicated on the plate, and referred to in the Botany of California, in the second volume of which a habitat is given. An interesting account of a botanical excursion to the Island of San Miguel concludes the number. A. G.

8. *Catalogue provisoire des Plantes Phanerogames et Cryptogames de la Basse Louisiane, Etats-Unis d'Amerique*, par A. B. LANGLOIS, Pointe-a-la-hache, Louisiana.—This is a list of the plants at the mouth of the Mississippi, collected and determined by the Rev. M. Langlois, a parish priest whose zeal, knowledge, and success in botany are notable. It is well to have a catalogue of the plants of that district. Among the species which have been borne to that shore from the south are *Cuphea glutinosa*, *Polygonum Meisnerianum*, *Cyperus Surinamensis*, and *Luziola Peruviana.* A. G.

9. *The Development of the Ostrich Fern, Onoclea Struthiopteris*, by Dr. DOUGLASS H. CAMPBELL, is a neat memoir published by the Boston Society of Natural History (iv, no. 2, 1887) pp. 35, and 4 plates, 4to, as the Walker Prize Essay of 1886. It appears to be a faithful piece of detailed work. It would have been well to append a statement of what had already been done in nearly the same field. A. G.

10. *Studi botanici sugli Agrumi e sulle piante affini.* Rome, 1887. By O. PENZIG.—This elaborate memoir of nearly 600 pages of text and an atlas of 58 folio plates appeared in the Annali di Agricultura, published under the direction of the Italian

Minister of Agriculture, Industry and Commerce. The author states that he has been at work on the question proposed by the minister, "the study of the structure, vital functions and diseases of the *Citri*," since the year 1879, and the memoir is the most complete work on the subject that has as yet appeared. A third of it is devoted to the morphology and histology of *Citrus* and related genera; this is followed by chapters on the comparative anatomy of the *Aurantiaceæ*. Part third treats briefly of the chemical properties of the *Citri*; and part fourth is devoted to diseases of cultivated species caused by fungi and insects. The latter subject is discussed minutely and forms the most important part of the memoir. In two previous papers the author described 166 species of fungi parasitic on *Citri*, and the number has been increased to 190 in the present volume. The plates of fungi appeared originally in the *Fungi Italice autographice delineati* of Saccardo. The memoir ends with a full bibliography and index; the whole is beautifully printed and does great credit to the Italian government. W. G. F.

11. *Elements of Botany*, by Asa Gray. New York, 1887. 8vo, pp. 226.—This title was given by Dr. Gray to his first educational publication, more than fifty years ago. The earliest treatise has grown into the Text-Book, while this new work is designed to replace the well-known Lessons in Botany. No confusion is likely to result from the revival of the older name after the lapse of half a century, and its assignment to a wholly different book. The new work differs in many features from any of its predecessors. It embodies the grammar of Organography, the first principles of Vegetable Physiology, and of Botanical classification, and gives with the help of an adequate glossary, directions for the description of plants. The bringing so much within so narrow a compass has been accomplished by giving the kernel of every topic without any husks. The "Elements" is designed to be the companion and interpreter of the "Manual" and kindred works, and will be bound up with these as the grammar and dictionary and handy work of reference. It is equally adapted to the wants of classes and of those who are obliged to study by themselves. G. L. G.

12. *Elements of Botany;* by Edson S. Bastin, A.M. Chicago, 1887. 8vo, pp. 282.—The author of this treatise states that there exists "a genuine need for some work on botany better adapted to the wants of our high schools, academies, and colleges of pharmacy and medicine than any in present use." The numerous excellent introductory works on botany, now before the English-reading public, have not made this want severely felt; but so long as teachers differ in their preferences as to methods of presenting a subject to their pupils, so long will some place be found for every new claimant upon the attention. Professor Bastin's work is methodical and trustworthy, and its scope is sufficiently wide for those whom it has been prepared to serve, except that it is not particularly pharmacological, as would be expected from the Professor in the College of Pharmacy at Chicago. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following is a list of the papers presented at the meeting held at Columbia College, New York, Nov. 8–10, 1887.

T. C. Mendenhall: Seismoscopes and Seismological investigations.

E. D. Cope: On the primary specializations of the True Fishes; On the mechanical origin of the structures of the hard parts of the Mammalia.

Wm. A. Rogers: A study of the behavior of metals under variations of temperature.

T. Sterry Hunt: Chemism in its relations to temperature and pressure; Progressive series in Chemistry.

J. D. Dana: Kilauea, a Basalt Volcano.

Henry Mitchell: Circulation of the Sea through New York Harbor.

Ogden N. Rood: On a study of Color Contrast.

W. K. Brooks: On the relative variability of men and women; On a new form of reproduction in Medusæ; On the Lucayan Indians.

A. M. Mayer: Experiments in measurements of statical electricity in absolute units; On Potential as measured by work, a mathematical discussion.

Theo. Gill: A comparison of Antipodal Faunas.

W. P. Trowbridge: On a discovery recently made in connection with the flight of birds.

E. C. Pickering: On the determination of star magnitudes by photography.

A. Hall: On the constant of aberration.

J. S. Newberry: The Cretaceous Coals of Western North America; The future of Gold and Silver Production.

S. P. Langley: The Temperature of the Moon.

A. A. Michelson and E. W. Morley: On a Method of making the wave-length of Sodium light the absolute standard of length.

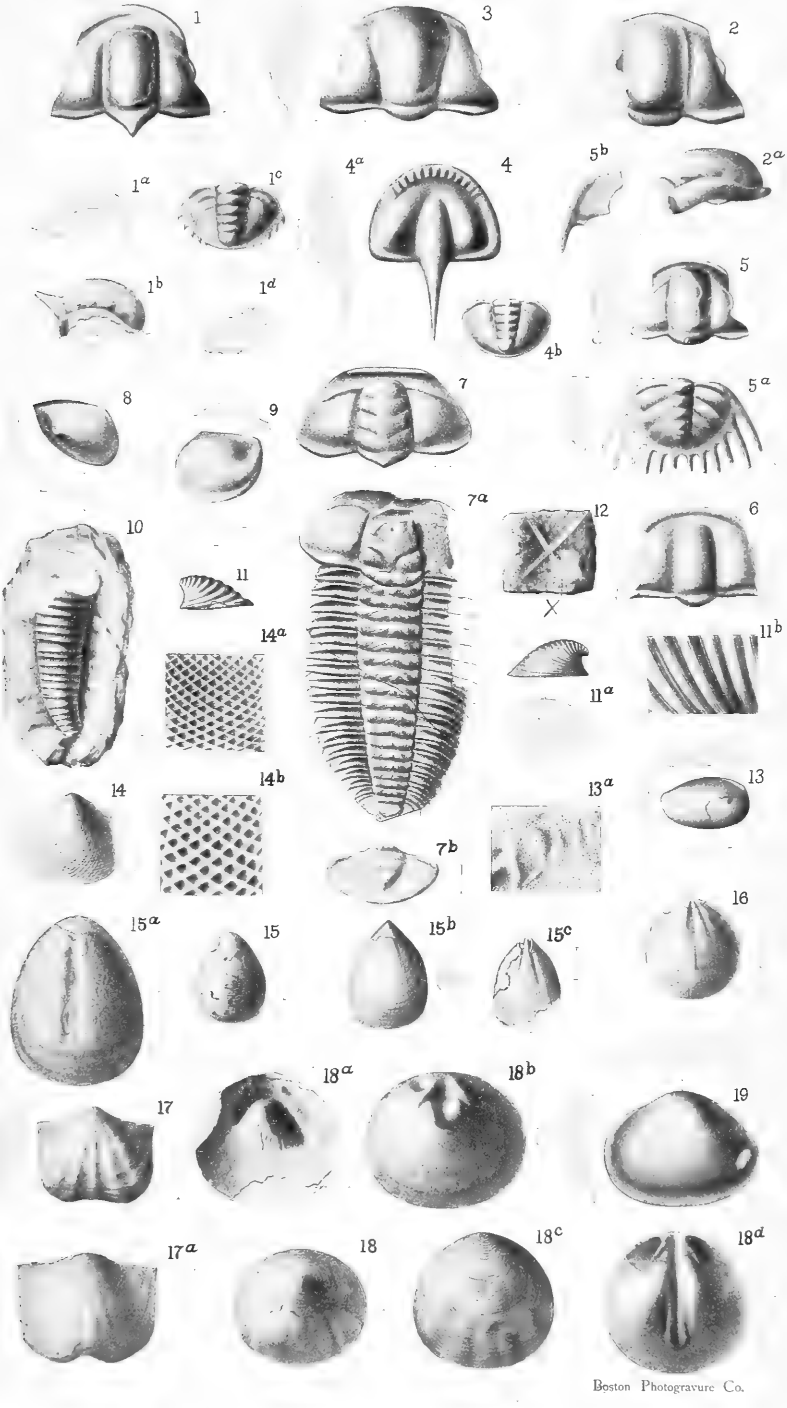
OBITUARY.

Gustav Robert Kirchhoff, Professor of Physics at Berlin, died on the 17th of October, in his 64th year. His death removes from the ranks of physicists one who has long held a foremost place and to whom the world of Science owes some of the most important steps of progress it has made. His first paper was published in 1845, and from that time until the later years of his life, when his health was seriously impaired, his contributions were numerous, varied in subject, and of a high order. First of all in importance come his contributions to spectrum analysis, a department of Physics largely created by him and by Prof. Bunsen, his colleague at Heidelberg where the work was done; this was in 1859 and 1860. Prior to this date his attention had been largely devoted to electrical subjects, and his papers upon Ohm's law, the discharge of the Leyden Jar and kindred topics, are all of great value. Still another series was devoted to investigations on the equilibrium and motion of elastic solids, and his work entitled Lectures on Dynamics (1876), is well known. A collection of his papers was issued at Leipzig in 1882.

Oscar Harger, assistant in the Paleontological department of Yale University, died on November 6th. A notice is deferred until a later number.

INDEX TO VOLUME XXXIV.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.



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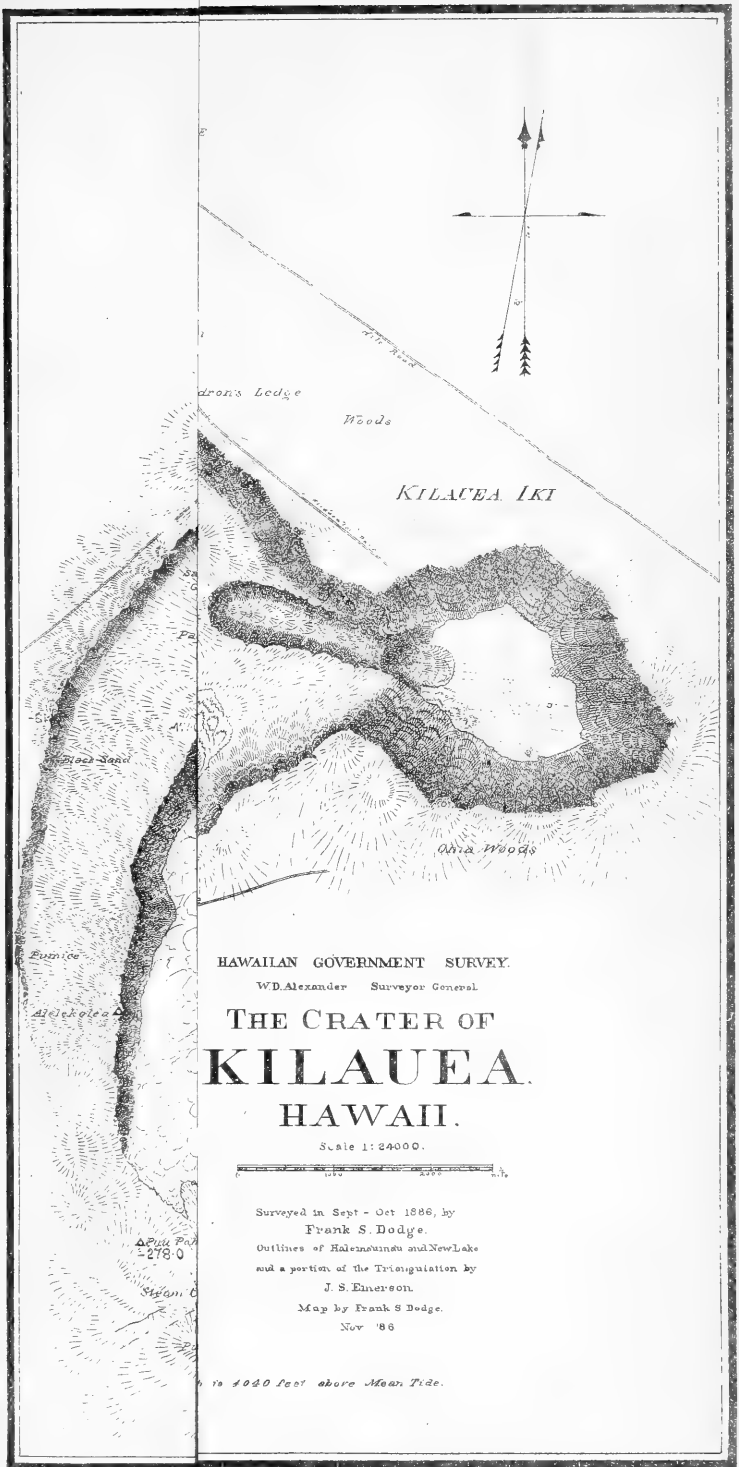
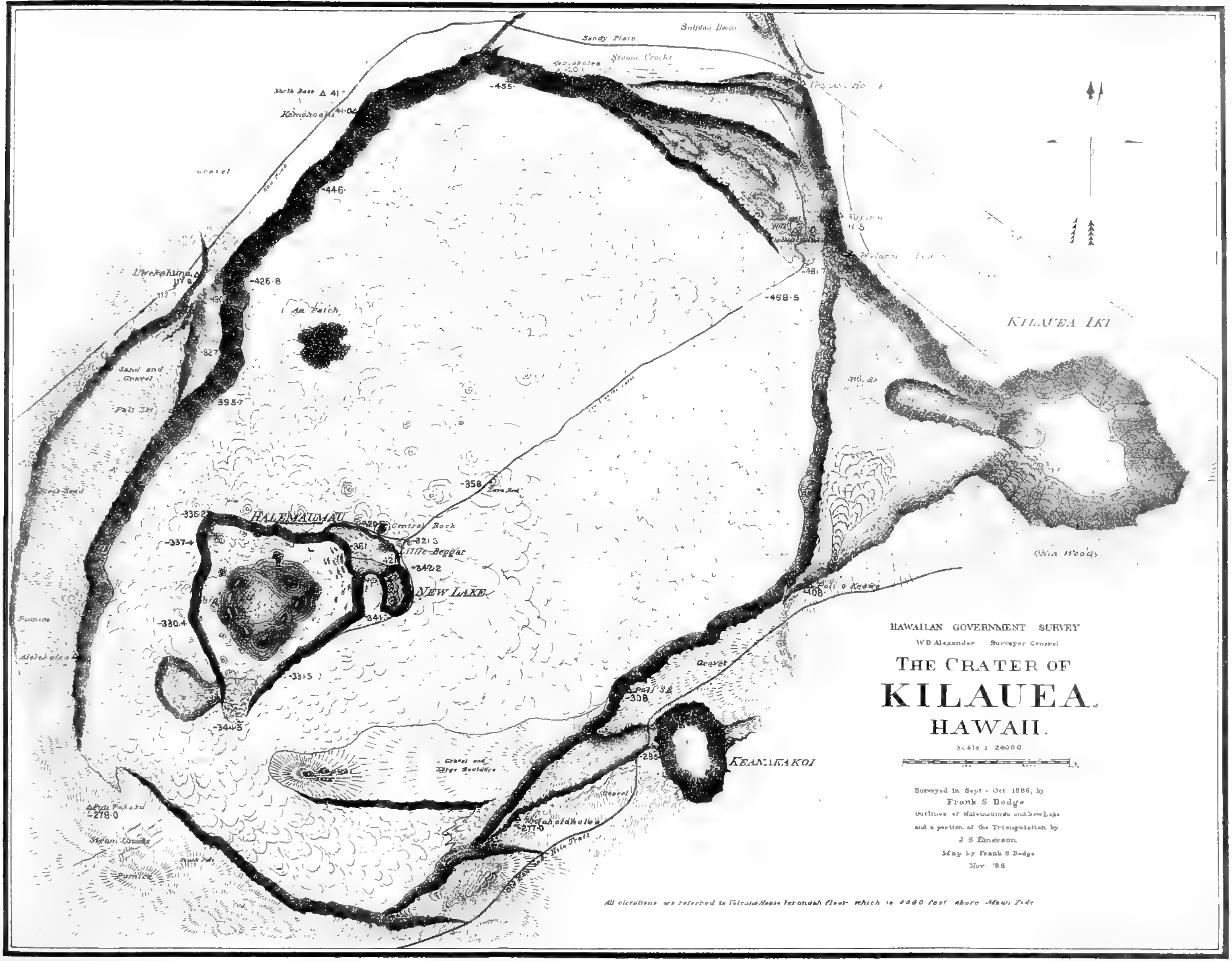
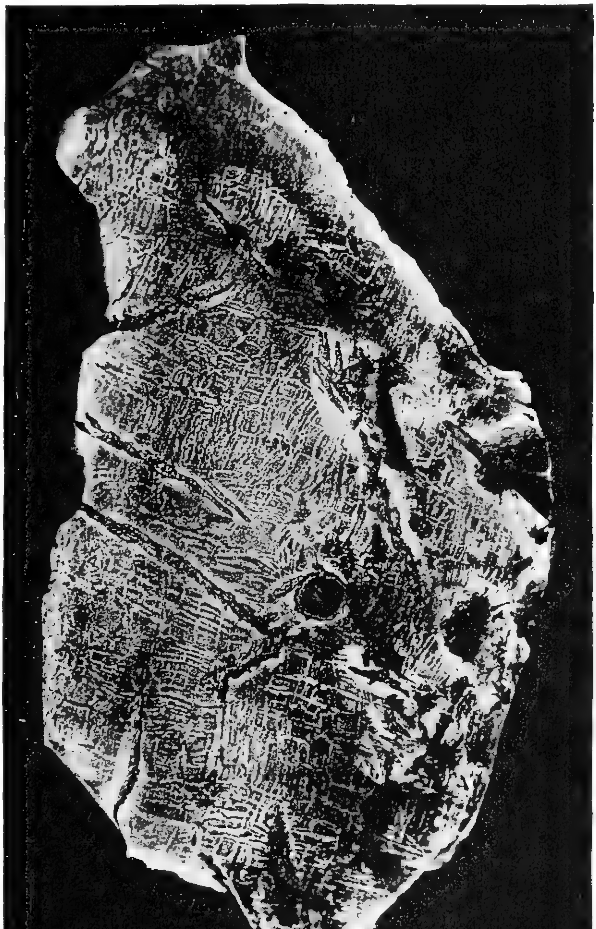


Photo Lith L.S. Punderson, New Haven Ct


HAWAIIAN GOVERNMENT SURVEY
W D Alexander Surveyor General
THE CRATER OF
KILAUEA,
HAWAII.
Scale 1 24000
Surveyed in Sept - Oct 1886, by
Frank S Dodge
Map by Frank S Dodge
Nov '86
KILAUEA IKI
HALEMAUMAU
NEW LAKE
KEANAKAKOI
Central Rock
Little Beggar
Sandy Plain
Sulphur Banks
Steam Cracks
Uwekahuna
Aa Patch
Sand and Gravel
Pumice
Gravel and Large Boulders
Ohia Woods
Steam Cracks
Pumice
Hilo Trail
-455
-446
-426·8
-468·5
-395·7
-358
-336·2
-337·4
-361
-321·3
-342·2
-341
-330·4
-331·5
-344·5
-308
-285
-278·0
All elevations are referred to Volcano House verandah floor which is 4040 feet above Mean Tide

North end of the Halema'uma'u basin and of the debris-cone within it; and above the west wall of the basin, the walls of Kilauea and the dome, Mt. Loa.

LAVA FLOOR OF KILAUEA.



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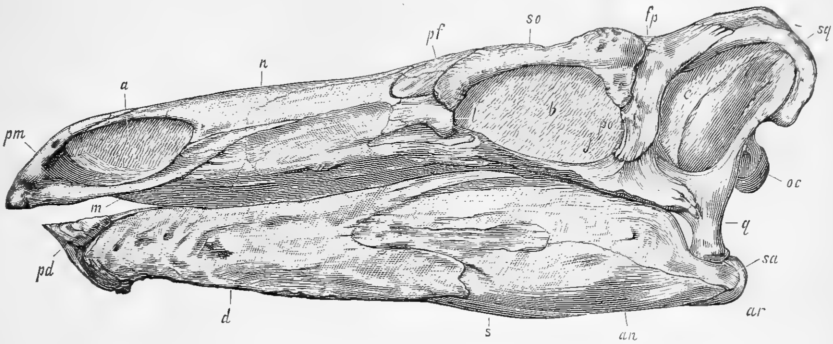

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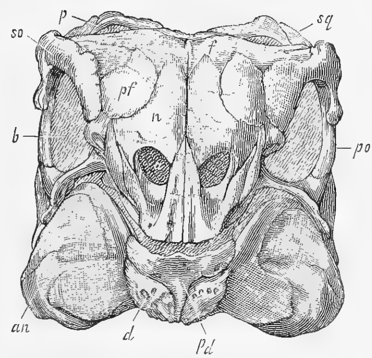

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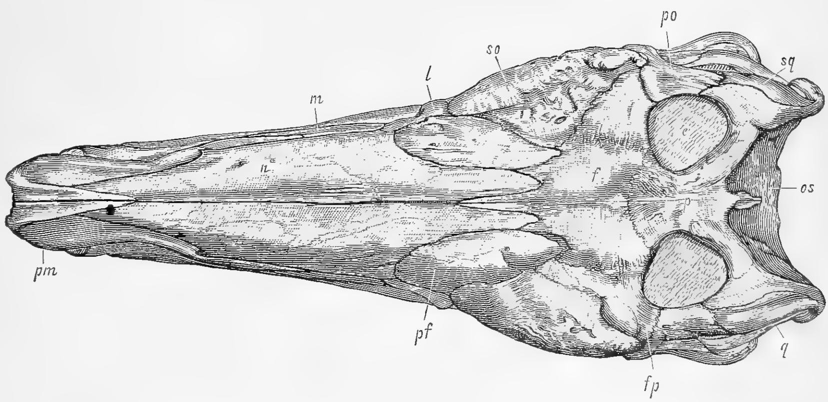


FIGURE 1.—Skull of *Stegosaurus stenops*, Marsh; side view.
FIGURE 2.—The same specimen; front view.
FIGURE 3.—The same specimen; top view.
All the figures are one-fourth natural size.

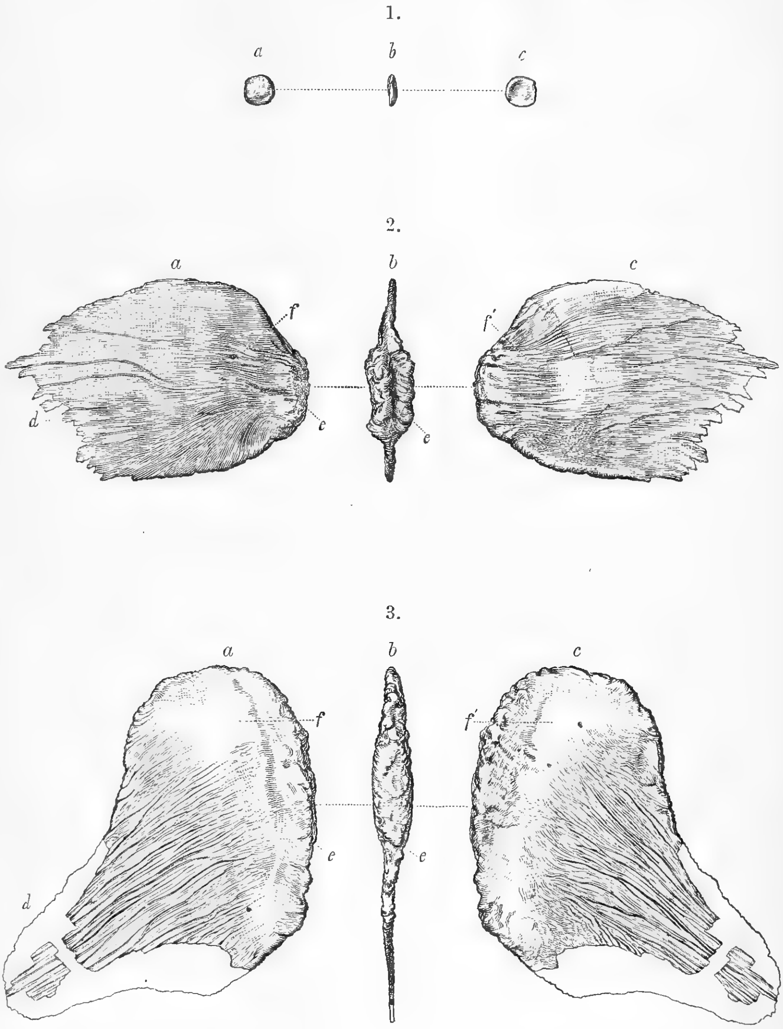


FIGURE 1.—Gular plate of *Stegosaurus ungulatus*, Marsh; *a*, superior view; *b*, side view; *c*, inferior view.

FIGURE 2.—Caudal plate of same individual; *a*, side view; *b*, end view of base; *c*, view of opposite side; *d*, thin margin; *e*, rugose base; *f*, and *f′*, surface marked by vascular grooves.

FIGURE 3.—Dorsal plate of same individual; *a*, right side; *b*, thick basal margin; *c*, left side; other letters as in last figure.

All the figures are one-twelfth natural size.

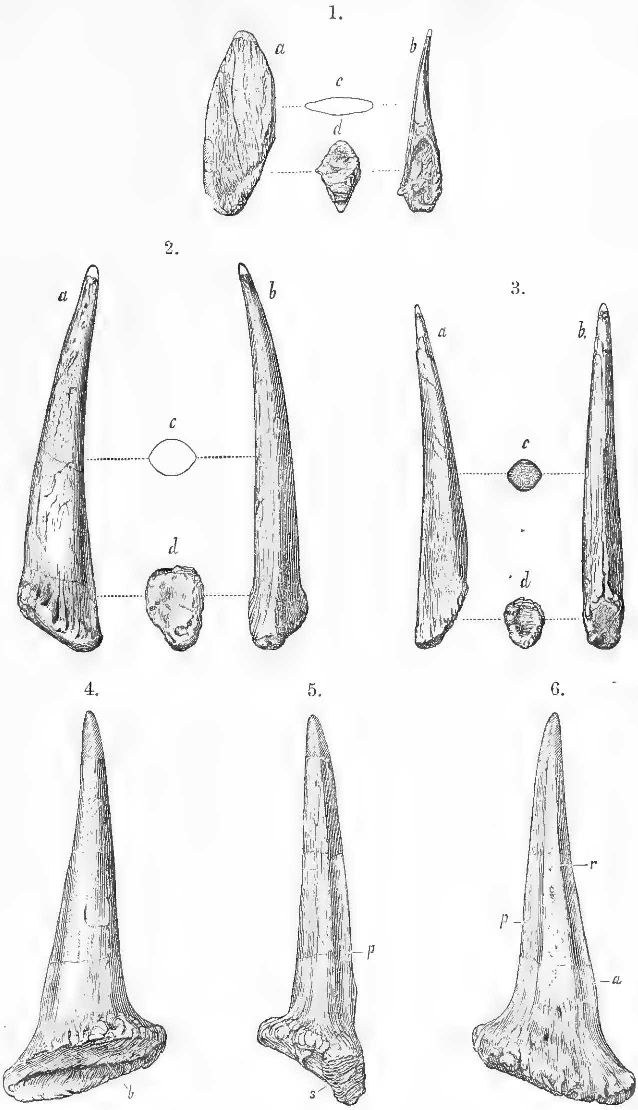
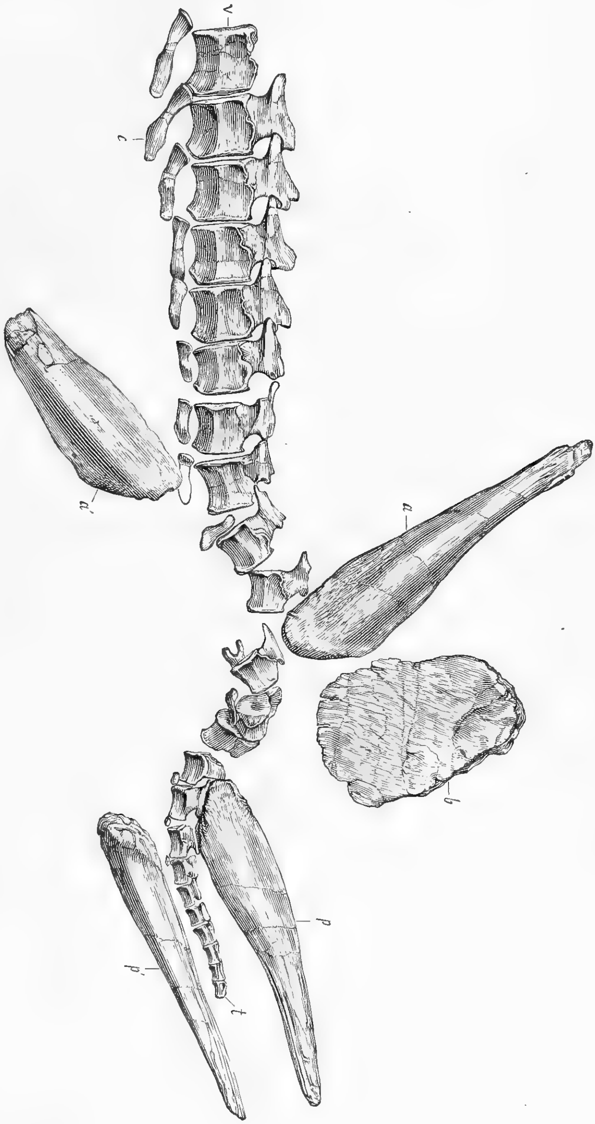
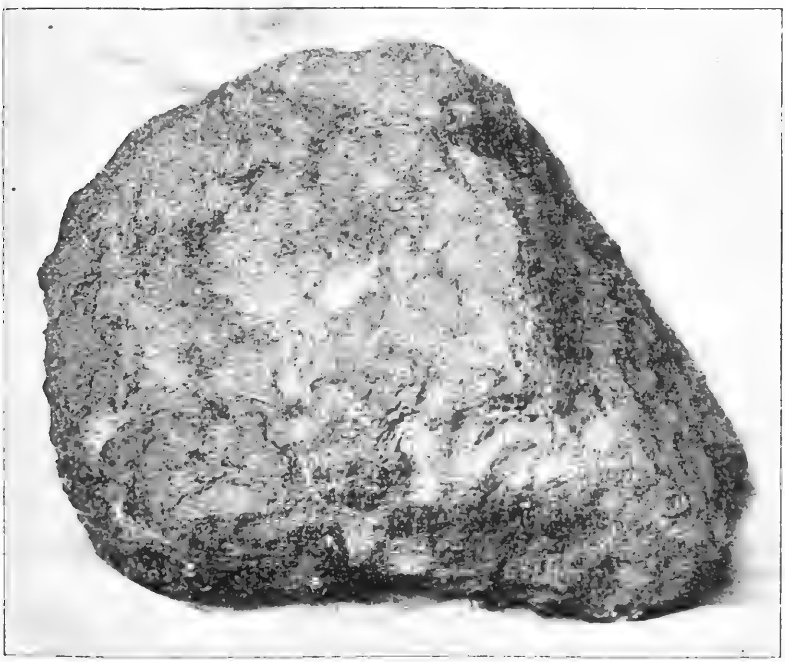


FIGURE 1.—Dorsal spine of *Stegosaurus ungulatus*, Marsh; *a*, side view; *b*, posterior view; *c* section; *d*, inferior view of base.
FIGURE 2.—Large caudal spine of same individual; *a*, side view; *b*, front view; other letters as above.
FIGURE 3.—Smaller caudal spine of same individual; *b*, posterior view; other letters as above.
FIGURE 4.—Caudal spine of *Stegosaurus sulcatus*, Marsh; side view.
FIGURE 5.—The same spine; posterior view.
FIGURE 6.—The same spine; inner view.
All the figures are one-twelfth natural size.



Caudal vertebræ, spines, and plate of *Diracodon laticeps*, Marsh; seen from the left. One-sixth natural size.
a, right anterior spine; *a'*, left anterior spine; *b*, small caudal plate; *c*, chevron bone; *p*, right posterior spine; *p'*, left posterior spine; *t*, terminal vertebra; *v*, median caudal vertebra.



TANEY COUNTY, MISSOURI, METEORITE.

Williams

CONTENTS.